ARE SUPERWEEDS AN OUTGROWTH OF USDA BIOTECH POLICY? (PART I)

HEARING

BEFORE THE

SUBCOMMITTEE ON DOMESTIC POLICY

OF THE

COMMITTEE ON OVERSIGHT AND GOVERNMENT REFORM

HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

SECOND SESSION

JULY 28, 2010

Serial No. 111–158

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ARE SUPERWEEDS AN OUTGROWTH OF USDA BIOTECH POLICY? (PART I)

WEDNESDAY, JULY 28, 2010

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON DOMESTIC POLICY,
COMMITTEE ON OVERSIGHT AND GOVERNMENT REFORM,
Washington, DC.

The subcommittee met, pursuant to notice, at 2 p.m., in room 2154, Rayburn House Office Building, the Honorable Dennis J. Kucinich (chairman of the subcommittee) presiding.

Present: Representatives Kucinich, Cummings, Foster, Kaptur, Jordan, and Schock.

Staff present: Jaron R. Bourke, staff director; Justin Baker, clerk/policy analyst; Leneal Scott, IT specialist, full committee; Justin LoFranco, minority press assistant and clerk; and Marvin Kaplan, minority counsel.

Mr. KUCINICH. The Subcommittee on Domestic Policy of the Committee on Oversight and Government Reform will now come to order.

Farmers have known for years that a potentially devastating problem was growing in their fields: weeds that herbicides may not be able to control. To provide a visual demonstration of the problem that this hearing addresses, I ask that you look at the monitors for an excerpt from an ABC News segment that ran last year.

[Video shown.]

Mr. KUCINICH. Today's hearing is the first held by Congress to examine the environmental impact of the evolution of herbicide-resistant weeds in fields growing genetically engineered herbicide-resistant crops. This is also the first day of a two-part hearing. We will hear from the U.S. Department of Agriculture in September.

Without objection, the Chair and ranking minority member will have 5 minutes to make opening statements, followed by opening statements not to exceed 3 minutes by any other Member who seeks recognition. And without objection, Members and witnesses may have 5 legislative days to submit written statements or extraneous materials for the record.

In farm fields across the Southeast and Midwest, a new crop has been sprouting among the rows of genetically engineered, Roundup Ready soy, corn and cotton. Familiar weeds have rapidly evolved a significant new trait: they can no longer be controlled by the herbicide Roundup. Herbicide resistant weeds such as pigweed, horseweed, water hemp, giant ragweed, palmer amaranth and common lambs quarters, have infested millions of acres of prime farm land. Some can grow three inches per day, reach a height of seven feet, and have stalks as thick as baseball bats. They can destroy farm equipment.

When the U.S. Department of Agriculture allowed the commercialization of Roundup Ready crops, the results were supposed to be bigger yields, better profits for farmers and less pollution from herbicides. Though it has been little more than 10 years, for many farmers these promised benefits seem like a distant memory. The natural selection of herbicide-resistant weeds in farm fields growing Roundup Ready crops is an indirect negative consequence of a technology that was purported to be nearly miraculous. And it is totally canceling out the alleged benefits of genetically engineered herbicide-resistant crops.

Rather than fewer herbicides, farmers have been using more herbicides and more toxic ones. In fact, Monsanto Co., the manufacturer of Roundup, spent years erroneously advising farmers to exclusively use ever greater quantities of Roundup to control the weeds in their fields. And for years, farmers listened.

Meanwhile, these weeds were receiving evolutionary pressure to select for a trait of resistance to Roundup. The Roundup-resistant trait is now dominant in weeds growing in many areas of the country.

The introduction of genetically engineered plants is regulated by the Animal and Plant Health Inspection Service of the USDA pursuant to its authority under the Plant Protection Act. Where was the USDA while the weed problem that imperils modern agriculture practices was developing? In courtrooms across the country, USDA has been rebuked for having unreasonably and arbitrarily dismissed the environmental consequences of deregulating genetically engineered crops. In some cases, Federal judges have found that the USDA could produce no written record that it had ever considered the impact on farmers.

Thus, a Federal district court invalidated USDA's decision to deregulate Roundup Ready alfalfa. USDA is now awaiting further directions from a Federal judge before taking further steps to consider whether and on what terms to deregulate this crop.

Since taking office, Secretary Vilsack has promised that the new administration would take a fresh look at biotech crop policy. But the biotech industry isn't waiting for new policy. Chemical industry giants, such as Dow, BASF and Syngenta are plowing forward with new varieties of soy, corn and cotton. They are already asking USDA to deregulate seed varieties that have been genetically engineered to tolerate their own herbicides.

In fact, the evolution of Roundup-resistant weeds, while a problem for Monsanto, has been an opportunity for other large chemical companies.

The immediate consequences of the deregulation and planting of these multiple herbicide-tolerant crops will be the increase in use of more toxic herbicides. Dicamba and 2,4-D are more toxic than Roundup and their increased use can only be regarded as a setback for sustainable agriculture.

In the longer term, the herbicide resistance of the weeds themselves could further change. If Roundup-resistant weeds evolved in only 10 years, could multiple-herbicide-resistant weeds be far away? I am going to ask that question again. If Roundup-resistant weeds evolved in only 10 years, could multiple-herbicide-resistant weeds be far away?

Indeed, several species of weeds already exhibit multiple-herbicide resistance. The development of more multi-herbicide-resistant weeds possess a very serious threat to agriculture in the United States as we know it. The increased expense for mechanical and hand labor to remove herbicide-resistant crops on today's colossal farms could be cost prohibitive, potentially wreaking havoc on modern farming.

Until now, the USDA has deregulated without condition every herbicide-resistant seed variety that industry has produced. Will that pattern continue in the future? Does the USDA have the legal authority to attach conditions and restrictions or even to block the commercialization of genetically engineered herbicide-resistant crops? Will that agency use that authority?

Farmers have a long-term investment in their chief asset, their land. Chemical companies operate on a shorter horizon. Nature's reaction to farm practices since the introduction and marketing of genetically engineered herbicide-resistant crops has created a temporary opportunity for chemical companies, an opportunity they will pursue at the long-term expense of the Nation's farmers.

Now more than ever, farmers need a Department of Agriculture that takes care to preserve and protect the farming environment for generations to come.

I now recognize the ranking minority member from Ohio, Mr. Jordan.

[The prepared statement of Hon. Dennis J. Kucinich follows:]

Opening Statement of

Dennis J. Kucinich
Chairman
Domestic Policy Subcommittee
Oversight and Government Reform Committee

Hearing on

"Are 'Superweeds' an Outgrowth of USDA Biotech Policy? (Part I)"

July 28, 2010

In farm fields across the Southeast and Midwest, a new crop has been sprouting among the rows of genetically engineered, Roundup Ready soy, corn, and cotton. Familiar weeds have rapidly evolved a significant new trait: they can no longer be controlled by the herbicide Roundup. Herbicide-resistant weeds such as pigweed, horseweed, waterhemp, giant ragweed, palmer amaranth, and common lambsquarters have infested millions of acres of prime farmland. Some can grow three inches per day, reach a height of seven feet, and have stalks as thick as baseball bats. They can destroy farm equipment.

When the U.S. Department of Agriculture allowed the commercialization of Roundup Ready crops, the results were supposed to be bigger yields, better profits for farmers, and less pollution from herbicides. Though it has been little more than 10 years, for many farmers these promised benefits seem like a distant memory. The natural selection of herbicide-resistant weeds in farm fields growing Roundup Ready crops is an indirect negative consequence of a technology that was purported to be nearly miraculous. And it is totally cancelling out the alleged benefits of genetically engineered, herbicide-resistant crops.

Rather than fewer herbicides, farmers have been using more herbicides, and more toxic ones. In fact, Monsanto Company, the manufacturer of Roundup, spent years erroneously advising farmers to exclusively use ever-greater quantities of Roundup to control the weeds in their fields. And for years, farmers listened. Meanwhile, these weeds were receiving evolutionary pressure to select for a trait of resistance to Roundup. The Roundup resistance trait is now dominant in weeds growing in many areas of the country.

The introduction of genetically engineered plants is regulated by the Animal and Plant Health Inspection Service of the USDA, pursuant to its authority under the Plant Protection Act. Where was the USDA while a weed problem that imperils modern agricultural practices was developing? In courtrooms across this country, USDA has been rebuked for having unreasonably and arbitrarily dismissed the environmental consequences of deregulating genetically engineered crops. In some cases, federal judges have found that USDA could produce no written record that it had ever even considered the impact on farmers. Thus a federal district court invalidated USDA's decision to deregulate Roundup Ready Alfalfa. USDA is now awaiting further directions from a federal judge before taking further steps to consider whether, and on what terms, to deregulate this crop.

Since taking office, Secretary Vilsack has promised that the new Administration would take a fresh look at biotech crop policy. But the biotech industry isn't waiting for a new policy. Chemical industry giants such as Dow, BASF, and Syngenta are plowing forward with new varieties of soy, corn, and cotton. They are already asking USDA to deregulate seed varieties that have been genetically engineered to tolerate their own herbicides. In fact, the evolution of Roundup-resistant weeds, while a problem for Monsanto, has been an opportunity for the other large chemical companies.

The immediate consequence of the deregulation and planting of these multiple-herbicide tolerant crops will be the increase in use of more toxic herbicides. Dicamba and 2,4-D are more toxic than Roundup, and their increased use can only be regarded as a setback for sustainable agriculture. In the longer term, the herbicide resistance of the weeds themselves could further change. If Roundup-resistant weeds evolved in only 10 years, could multiple herbicide-resistant weeds be far away? Indeed, several species of weeds already exhibit multiple-herbicide resistance. The development of more multi-herbicide-resistant weeds poses a very serious threat to agriculture in the United States as we know it. The increased expense for mechanical and hand labor to remove herbicide-resistant crops on today's colossal farms could be cost-prohibitive, potentially wreaking havoc on modern farming.

Until now, USDA has deregulated, without condition, every herbicide-resistant seed variety that industry has produced. Will that pattern continue into the future? Does USDA have the legal authority to attach conditions and restrictions, or even to block the commercialization of genetically engineered, herbicide-resistant crops? Will the agency use that authority?

Farmers have a long-term investment in their chief asset, their land. Chemical companies operate on a shorter horizon. Nature's reaction to farm practices since the introduction and marketing of genetically engineered, herbicide-resistant crops has created a temporary opportunity for chemical companies, an opportunity they will pursue at the long-term expense of the nation's farmers. Now, more than ever, farmers need to have a Department of Agriculture that takes care to preserve and protect the farming environment for generations to come.

Mr. JORDAN. Thank you, Mr. Chairman.

I should have cleared this with the chairman first. I am just going to enter my statement into the record, if that is OK with the chairman.

Mr. KUCINICH. Without objection.

Mr. JORDAN. I know our member, Congressman Schock, has a statement that he would like to make at the appropriate time.

[The prepared statement of Hon. Jim Jordan follows:]

OPENING STATEMENT OF JIM JORDAN
RANKING MEMBER
SUBCOMMITTEE ON DOMESTIC POLICY
JULY 28th, 2010
HEARING: "ARE SUPERWEEDS AN OUTGROWTH OF USDA BIOTECH POLICY?"

Thank you Mr. Chairman.

Agriculture is one of the few industries that has not floundered in this recession. Net farm income is forecast to be $63 billion in 2010, up $6.7 billion or 11.8 percent from 2009.

Glyphosate resistant weeds, although currently isolated, could potentially destroy this profitability. Today, 346 resistant biotypes and 194 species of resistant weeds have developed in over 340,000 fields across the world, approximately .08 percent of fields world wide. Of the 11,673,050 acres of cropland in my home state of Ohio, 90,400 acres are infested with herbicide resistant weeds, less than one percent of Ohio's cropland.

To combat the development of herbicide resistant weeds, multiple groups are educating farmers on best weed control practices and biotech companies are creating incentive programs to promote these practices. Through such practices, weed resistance to the herbicide triazine, which first developed in the 1960s, has never become limiting.

At the same time, biotech companies are pursuing multiple herbicide resistant crops that offer growers more herbicide options to meet their changing weed management needs and to help sustain the efficacy of glyphosate. Unfortunately, since 1996, the time it takes the USDA to deregulate a genetically engineered plant has increased, on average, by more than 700 percent. This type of delay only exacerbates the herbicide resistant weed problem by limiting the availability of new crops.

The market is working effectively to control the development of herbicide resistant weeds. The government must work effectively to make the necessary tools available to combat this problem, not implement new obstacles.

I look forward to hearing about the efforts made by academia to educate farmers and combat the development of herbicide resistant weeds. Thank you.

Mr. KUCINICH. Did you want to yield to him?

Mr. JORDAN. I would be happy to yield to the gentleman.

Mr. KUCINICH. OK, we will enter your statement into the record and you can yield to him.

Mr. JORDAN. Thank you, Mr. Chairman. I yield to the Member from Illinois.

Mr. SCHOCK. Thank you, Mr. Jordan. Chairman Kucinich, I thank you for the opportunity to provide these opening remarks. As a Member of Congress who represents one of the 60 ag-dominant districts in the United States, this issue is of particularly great importance to the constituents I represent.

I would also like to thank our witnesses who traveled with us here today and are going to be testifying.

Before I begin, I would like to ask for unanimous consent to insert for the record a copy of remarks by the Illinois Farm Bureau and the Illinois Corn Growers, expressing shared concern about additional Government regulation of our Nation's farmers.

Mr. KUCINICH. Without objection.

Mr. SCHOCK. Thank you.

The title of today's hearing confuses me even more than the underlying premise. The attempt to link advancements to help farmers produce greater yields, become commercially viable and better stewards of their land and the environment to some sort of habitat negligence is totally befuddling to me. The underlying premise of this hearing is that farmers across this country are not employing the best management practices on their fields.

According to these assumptions, they have no concern about their long-term economic and environmental sustainabilty and are thus destroying their fields and the environment. With this view, only new Government regulation can combat these weeds.

I understand the purpose of this hearing is to reaffirm this belief, that by some unnatural process the use of genetically engineered seeds and the use of weed repellent have led to some unnatural superweed. Yet the facts couldn't be further from the truth.

U.S. growers have been growing herbicide-tolerant crops and using herbicides to control weeds for almost 60 years. Since 1980, 90 percent of the corn and soybeans grown in the United States have been herbicide-tolerant, grown in fields treated with herbicides. Because U.S. growers have been using herbicides for almost 60 years, they have been dealing with herbicide resistant for almost 50 years. Certain weed species will inevitably become resistant to some herbicides or any other control methodology, for that matter.

Neither the Government nor the grower can prevent resistance from occurring. Rather, they can employ those best management practices which will help them stay two steps ahead of the next generation of weeds, while remaining economically viable and successful.

If the goal today is to end the use of science and technology in the industry of agriculture, I would ask, how will the U.S. agriculture continue to play a role in feeding the world's 6½ billion people? Surely we can't do that by going in reverse and employing practices which will put our farming community at a competitive disadvantage.

In reality, I would argue the market controls already in place are more than enough to ensure farmers are employing the best practices to control herbicide-resistant weed growth on their fields. It is actually our farmers, not the Government, who are more concerned about the development of new herbicide-resistant weeds. And it is this concern which has already prompted them to employ crop and herbicide rotation and other best management practices to combat any weeds at the first sign of growth.

The farmer who employs these practices will lose less of his yield to weeds and be more profitable in the long run. And the farmer who doesn't, well, he won't be a farmer for very long. The fact of the matter is that farmers yield more efficient growth from fields than ever before. They have done this during the same period of time which these purported superweeds have begun taking over.

Farmers realize that over-use or reliance on any single product to mitigate weed growth quickly results in the need to use a new and more expensive product. As such, it is already in their own financial interests to rotate weed mitigation techniques.

In addition, the agriculture industry realizes that is in the best interest to mitigate extraneous weed growth as they spend tens of millions of dollars developing these products. In order to obtain return on their investments, these companies seek the use of their products over a long period of time. Selling an herbicide product that proves to be effective for only a few years is not a way to stay in business.

The laws of nature tell us that weeds will naturally become tolerant to any single mitigation practice. So why would we limit those practices a farmer may employ? What we should be talking about here is ensuring our farmers have all the tools necessary, the most complete playbook to mitigate weed growth, and not limit their options.

The real question here today seems to be, how much should we be regulating human behavior, and at what point do we say there are enough Government regulations and market controls in place that we can trust humans faced with a myriad of incentives to make the right decisions? Will there always be a handful of bad actors? Absolutely. But does that mean the Government should reach further into the lives of every farmer across the country with more regulations? I don't think so.

Do we tell a person how many calories he can consume each day or how many miles he or she can drive, or how long he can stay out in the sun? No. Rather, we try to educate our citizens with all the facts available about the decisions they are making, providing them with the tools necessary to make the right decisions. But ultimately, those decisions are theirs. We leave it up to each citizen to employ that practice, which will best ensure his or her long-term health, or in this case, their economic sustainabilty.

I yield back.

Ms. KUCINICH. The Chair recognizes the gentlelady from Ohio, Ms. Kaptur.

Ms. KAPTUR. Mr. Chairman, I just want to thank you very much for holding this hearing today. This is an issue in which I have been interested for a long time, particularly the exorbitant fees charged to farmers who use these various products to try to control weeds on their property. And we have tried to find ways to make the costs more bearable. I have a bill to do that.

And we see how unfair it is to many of our farmers when, if crops are planted in Latin America, let's say, versus here, and the fees are different, what a difference that makes in bottom lines here.

We are also coming from the Lake Erie area very interested in the long-term impact of the use of these products on our soil and ultimately on Lake Erie, our life source, because of the unexplained now-growing amount of algal blooms that are on Lake Erie. Some are hypothesizing it has to do with the fact that no-till has been used to such an extent that certain minerals do not break down in the soil in the same manner as if one tilled. And there are all kinds of theories now as to why we are getting these enormous algal blooms in Lake Erie and eutrophic areas for the first time, when we don't have oxygen in certain areas of the lake.

So we are looking at the connection between field agriculture, I live in the soybean bowl in the western basin of Lake Erie. And so we are trying to really understand the connection between crop practices, water flows, the health of the lake and the connection between herbicides and the long-term health of both the farm fields that the farmers are stewarding and then the water systems that serve us. I am not sure anyone completely understands it yet, but we know that there is something happening out there that is atypical.

So we thank you very much for holding this hearing today and we look forward to the witnesses' testimony.

Mr. KUCINICH. I thank the gentlelady.

Mr. Foster is recognized for 3 minutes.

Mr. FOSTER. Thank you. As a scientist and a businessman, I think what is needed here is a mature understanding of the situations in which the socialized risk of badly used mitigation controls is something that really makes it best for the Government to step in and regulate things. This is a very complicated thing. This is not an example of a situation where the free market incentives get the right idea. You can look at situations like just vaccines and antibiotic resistant bacteria as something where there are big socialized risks if individuals do not conduct proper control and proper use of these agents.

The other thing that concerns me about just letting the market do everything is the long time scale for developing agents that will continue to work as phenomenally well as the Roundup Ready varieties and the Roundup itself have well into the future. One of the things that I am worried about is that there actually hasn't been enough incentive to develop a variety of substitutes for Roundup-resistant crops and Roundup itself.

So I think that is something where we have to actually look at the science of this thing and understand, make our best estimate of how things are going to develop over time. In situations where you don't see the free market developing the right set of products that will have the huge, that will continue the huge economic and environmental benefits that we have seen from these, then I think that is something where the Government actually has a legitimate role to step in and to nudge people in the right direction.

I look forward to the testimony and thank the chairman and yield back.

Mr. KUCINICH. I thank the gentleman.

I want to continue by introducing our panel. Mr. Troy Roush is a fifth-generation farmer from central Indiana. The farm is located outside Van Buren in Grant County, approximately 75 miles northeast of Indianapolis. He farms on the same farm he was born and raised on with his father and two younger brothers. They grow corn, soybeans, wheat, popcorn, alfalfa and tomatoes on their 5,500 acre diversified farming operation. Mr. Roush also serves as vice president of the American Corn Growers Association.

Professor Micheal Owen has a Ph.D. in agronomy and weed science from the University of Illinois. He is associate chair and an extension weed scientist in the Department of Agronomy of Iowa State University. He has extensive expertise in weed dynamics, integrated pest management and crop risk management. His objective in extension program is to develop information about weed biology, ecology and herbicides that can be used by growers to manage weeds with cost-efficiency and environmental sensitivity. His work is focused on supportive management systems that emphasize a combination of alternative strategies and conventional technologies.

Dr. Owen has published extensively on farm-level attitudes toward trans-genic crops and their impacts, selection pressure, herbicide resistance and other weed life history traits and tillage practices. He recently served on the National Research Council Committee on the Impact of Biotechnology on Farm Level Economics and Sustainabilty.

Professor Stephen Weller is professor of weed science in the Department of Horticulture and has been at Purdue University for 30 years. He has responsibilities for research, teaching and extension and has taught courses in weed science, organic horticulture product and for 22 years was coordinator of the Purdue University herbicide action course. Research interests include weed biology, herbicide mode of action, resistance mechanisms to herbicides in crops and weeds, non-chemical weed management and integrated weed management vegetable crops.

He has extensive international experience working on integrated pest management and vegetable cropping systems in the developing world. Dr. Weller co-authored the text, Weed Science: Principles and Practices, Fourth Edition, seven book chapters, over 70 referred journal articles, over 100 research abstracts and 35 miscellaneous research extension publications.

Professor David Mortensen has advanced degrees in ecology and agronomy from Duke and North Carolina State University. He has worked in the field of weed management and ecology for the past 23 years in Midwestern agriculture at the University of Nebraska and in the Eastern United States at Penn State, where he currently holds a full professorship in the Department of Crop and Soil Sciences.

Professor Mortensen has researched and written widely on integrated methods of weed management, herbicide-resistance management, and the ecology that underpins weedy plant population dynamics. Professor Mortensen is the author of over 120 papers and book chapters on this body of research. He has also chaired the flagship National Competitive Grants Program in weed or integrated pest management four times in the past 10 years. Most recently in 2009, he chaired the Weedy and Invasive Organisms Competitive Grants Program with the USDA.

Finally, Mr. Andrew Kimbrell is founder and executive director of the Center for Food Safety in the International Center for Technology Assessment in Washington, DC. He is one of the country's leading environmental attorneys and an author of numerous books and articles on environment, technology, society and food issues. His books include 101 Ways to Help Save the Earth; The Human Body Shop; The Engineering and Marketing of Life; Your Right To Know; Genetic Engineering and Secret Changes in Your Food; and general editor of Fatal Harvest: The Tragedy of Industrial Agriculture.

His articles on law, technology, social and psychological issues have also appeared in numerous law reviews, technology journals, popular magazines and newspapers across the country. He has been featured in numerous documentaries including the film The Future of Food. In 1994, the Aetna Reader named Mr. Kimbrell as one of the world's leading 100 visionaries. In 2007, he was named one of the 50 people most likely to save the planet by the Guardian U.K.

I want to thank each and every one of our witnesses for being here. It is the policy of the Committee on Oversight and Government Reform to swear in all witnesses before they testify. I ask that you rise and raise your right hands.

[Witnesses sworn.]

Mr. KUCINICH. Thank you very much.

Let the record reflect that each and every one of the witnesses answered in the affirmative.

I would ask that each witness give an oral summary of your testimony, and keep the summary under 5 minutes in duration. Your entire written statement will be included in the hearing record. So it is much appreciated that you help us on this.

Mr. Roush, you are the first witness on this panel. We ask that you begin.

STATEMENT OF TROY ROUSH, FARMER, VAN BUREN, IN, VICE PRESIDENT, AMERICAN CORN GROWERS ASSOCIATION; MICHEAL D.K. OWEN, PH.D., PROFESSOR OF AGRONOMY, IOWA STATE UNIVERSITY; STEPHEN C. WELLER, PROFESSOR OF HORTICULTURE, PURDUE UNIVERSITY; DAVID A. MORTENSEN, PROFESSOR OF WEED ECOLOGY, PENNSYLVANIA STATE UNIVERSITY; AND ANDREW KIMBRELL, EXECUTIVE DIRECTOR, CENTER FOR FOOD SAFETY

STATEMENT OF TROY ROUSH

Mr. ROUSH. Thank you. Good afternoon, Chairman Kucinich, Ranking Member Jordan and members of the House Committee on Oversight and Government Reform, Subcommittee on Domestic Policy.

Before beginning my testimony, I want to thank the Chair for this invitation to address the issue of glyphosate-tolerant weeds and the crisis that it presents to U.S. farmers and American agriculture.

My name is Troy Roush. I farm 5,500 acres with my father and brothers in Central Indiana. We grow soybeans, corn, wheat, both conventional and organic, as well as popcorn and tomatoes. I also serve as Vice President of the American Corn Growers Association. I am here today to discuss how glyphosate-tolerant weeds affect my farming operation and many others in production agriculture.

I have been using genetically engineered soybeans since 2000, when a lawsuit for patent infringement against my family was dropped by Monsanto. After having endured 2 years of costly litigation that took its toll on my family, we decided that, in order to protect ourselves from future baseless lawsuits, we would make the conversion to biotech crops and began using Roundup Ready varieties for our non-organic crops.

During the first few years we were able to rely exclusively on Roundup Ready technology for weed management, applying glyphosate for burn-down and again to eliminate weed pressure after the crop emergence. However, due to problems with glyphosate tolerant weeds, and skyrocketing costs of Roundup Ready seeds and the price premiums being paid for non-genetically engineered soybeans, we have since returned to using conventional varieties on approximately half of our 2,600 soybean acres. The diminishing effectiveness of glyphosate, as demonstrated in the dramatic increase in glyphosate-tolerant weeds, is devaluing the technology.

Fortunately, Indiana enacted farmer protection laws in 2002 after and because of the lawsuit with Monsanto to prohibit patent infringement cases where small amounts of genetically engineered content is detected in crops and fields. Without those protections, our return to conventional soybean production would have brought with it the potential of significant risk of patent infringement liability.

After 2005, we first began to encounter problems with glyphosate-resistant marestail and lambsquarters in both our soybean and corn crops. Since there had been considerable discussion in the agricultural press about weeds developing resistance or tolerance to Roundup, I contacted a Monsanto weed scientist to discuss the problems I was experiencing on the farm and what could be done to eradicate the problematic weeds. Despite well-documented proof that glyphosate-tolerant weeds were becoming a significant problem, the Monsanto scientist denied that resistance existed and instructed me to increase my application rates.

The increase in application rates proved ineffectual, and I was forced to turn to alternative methods for weed management, including the use of tillage and other chemistry. In 2007, the weed problems had gotten so severe that we turned to an ALS inhibitor marketed as Canopy to alleviate the problem in our pre-plant, burndown herbicide application. In 2008, we were forced to include the use of 2,4-D and an ALS residual in our herbicide programs. Like most farmers, we are very sensitive to environmental issues and we were very reluctant to return to using tillage and more toxic herbicides for weed control. However, no other solutions were then or are now readily available for the eradication of weed problems caused by development of glyphosate resistance.

As I mentioned earlier, I have now returned to the use of conventional soybean varieties for about half my total acreage. That proportion of acreage will increase if supply of quality conventional seed varieties increases. While conventional soybean varieties have been very difficult to find, a small number of independent companies are now beginning to respond to demand. Conventional soybean seeds provide significant cost savings as compared to Roundup seeds. This year, Roundup soybeans cost $50 a bag which translates to $65 an acre. The conventional varieties planted from saved seed are about $15 an acre.

Since the weed management and herbicide costs are now roughly the same because of resistant Roundup Ready weeds, the difference seed costs using the conventional variety represents pure profit. I not only reduced production costs through the use of conventional soybean varieties, but last year I received a 20 percent price premium on my non-genetically engineered soybeans. Last year that translated to an additional $80,000 in additional profit.

Mr. KUCINICH. Mr. Roush, your time has expired. What I would like you to do is just take a minute to sum up, please.

Mr. ROUSH. Sure.

I guess the subject I want to talk about most is the solution, the potential solution, which is Dicamba. Anyone who has witnessed or has any experience with Dicamba has witnessed its volatility. We are not talking about pesticide drift in this context. I have seen Dicamba rise from fields, move across the ground, damaging any vegetables, soybeans, fruit, flowers, gardens in its path. Dicamba is not widely used by farmers for this reason. Even so, as recently as 2008, I had Dicamba destroy 20 acres of tomatoes.

Some would argue that it is not Government's role to stifle innovation by regulating the commercialization of these crops. But can we trust industry to regulate itself? The history of the American farmers shows that the answer to that question is a resounding no.

[The prepared statement of Mr. Roush follows:]

HOUSE COMMITTEE ON OVERSIGHT & GOVERNMENT REFORM
SUBCOMMITTEE ON DOMESTIC POLICY

ARE SUPERWEEDS AN OUTGROWTH OF USDA BIOTECHNOLOGY POLICY

STATEMENT OF TROY ROUSH
July 28, 2010

Good Afternoon Chairman Kucinich, Ranking Member Jordan and Members of the House Committee on Oversight and Government Reform, Subcommittee on Domestic Policy. Before beginning my testimony, I want to thank the Chair for this invitation to address the issue of glyphosate tolerant weeds and the crisis that it presents for the U.S. farmer and American agriculture.

My name is Troy Roush and I farm approximately 5500 acres with my father and brothers in central Indiana. We grow corn, soybeans and wheat – both conventional and organic – as well as popcorn and tomatoes. I also serve as Vice President of the American Corn Growers Association. (ACGA). I am here today to discuss how glyphosate tolerant weeds affect my farming operation and many others in production agriculture.

I have been using genetically engineered (GE) soybeans since 2000, when a lawsuit for patent infringement against my family was dismissed by Monsanto. After having endured two years of costly litigation that took its toll on my family, we decided that, in order to protect ourselves from future baseless lawsuits, we would make the conversion to biotech crops and began using Roundup Ready (RR) varieties for our non-organic crops.

During the first few years we were able to rely exclusively on RR technology for weed management, applying glyphosate for burndown and again to eliminate weed pressure after the crop emerge. However, due to problems with glyphosate tolerant weeds, the skyrocketing costs of RR seeds and the price premiums being paid for non-GE soybeans, we have since returned to using conventional varieties on approximately half of our 2,600 soybean acres. The diminishing effectiveness of glyphosate, as demonstrated in the dramatic increase in glyphosate tolerant weeds, destroyed any benefit from the technology.

Fortunately, Indiana enacted Farmer Protection laws in 2002 after my lawsuit with Monsanto to prohibit patent infringement cases where small amounts of GE content is detected in crops and fields. Without those protections, our return to conventional soybean production would have brought with it the potential of significant risk of patent infringement liability.

In 2005, we first began to encounter problems with glyphosate resistance in marestail and lambsquarter in both our soybean and corn crops. Since there had been considerable discussion in the agricultural press about weeds developing resistance or tolerance to Roundup, I contacted a Monsanto weed scientist to discuss the problems I was experiencing on the farm and what could be done to eradicate the problematic weeds. Despite well documented proof that glyphosate tolerant weeds were becoming a significant problem, the Monsanto scientist denied that resistance existed and instructed me to increase my application rates.

The increase in application rates proved ineffectual, and I was forced to turn to alternative methods for weed management including the use of tillage and other chemistry. In 2007, the weed problems had gotten so severe that we turned to an ALS inhibitor marketed as Canopy to alleviate the problem in our preplant, burndown herbicide application. In 2008, we were forced to include the use of 2,4D and an ALS residual, to our herbicide programs. Like most farmers, we are very sensitive to environmental issues and we were very reluctant to return to using tillage and more toxic herbicides for weed control. However, no other solutions were then or are now readily available to eradicate the weed problems caused by development of glyphosate resistance.

Originally, we were attracted to GE crop technologies for the ease of use and convenience associated with the crops. Time was saved by not having to do pre and post plant tillage for weed control, and herbicide tolerant varieties simplified pesticide use by eliminating the need for precise timing of applications. Those benefits have now been lost as a consequence of glyphosate tolerant weeds.

The increased ease of use and convenience of herbicide tolerant crops enabled many farmers to significantly increase crop acreage which helped to offset higher production costs and, in some cases, lower yields. Biotech companies encouraged farm expansion by offering discounts for buying seed in bulk. The advent of glyphosate tolerant weeds necessitated the return to using tillage for weed control, eliminating the time savings that was initially afforded by using biotech crops. Farmers that expanded farm size are now finding it difficult, if not impossible, to manage the larger operations now that additional time is required for weed management.

Eradicating glyphosate tolerant weeds has also significantly increased production costs. The addition of Canopy to my pesticide management program has added $7.00/acre to my production costs, while the use of 2,4D costs an additional $1.75/acre. This compares to the $2.25/acre in glyphosate (RR) costs.

As I mentioned earlier, I have now returned to the use of conventional soybean varieties for about ½ of my total acreage. That proportion of acreage will increase if supply of quality conventional seed varieties increases. While conventional soybean varieties have been very difficult to find, a number of small, independent seed companies are now beginning to respond to the demand. This year, I was able to find convention seeds from a small seed company that sources germplasm from an Ohio breeding program that allowed me to increase acreage in conventional varieties.

Conventional soybean seeds provide significant cost savings as compared to RR seeds. This year, RR soybeans cost $50/bag which translates to $65/acre. The conventional varieties that were planted from saved seed cost about $15/acre to plant while the conventional seeds that I purchased this year cost $22/bag or $28.50/acre. Since the weed management/herbicide costs are nearly the same for both conventional and RR soybeans, the seed costs dramatically reduce overall production costs in the conventional system. Since there is virtually no difference in yields between the conventional and RR varieties, the difference in seed costs using the conventional varieties represents pure profit.

I not only reduce production costs through the use of conventional soybean varieties, but last year I receiving a 20% price premium for my non-GE soybeans. Last year that translated to an additional $80,000 in profit.

These experiences are similar to that of many fellow Heartland grain producers. Short term, we can go back to using tillage and more toxic herbicides as a solution to the glyphosate tolerant weed problems, but that solution is short sighted and wrong-headed, as well as are the alternatives being contemplated by the biotechnology companies and the agri-chemical industry.

Mother Nature has repeatedly demonstrated an ability to thwart chemical cure-alls. We need to learn from our past mistakes or we are doomed to repeat them. Genetically engineering crops that are resistant to multiple pesticides are a disaster waiting to happen, particularly if those tolerances include pesticides such as atrazine, dicamba and 2,4D which would bring us full circle back to the use of the highly toxic pesticides that glyphosate and herbicide tolerant crops were supposed to eliminate forever.

While the problems associated with glyphosate tolerant weeds can arguably be solved through increased tillage and the use of other chemical pesticides, the subsequent development of weeds that are resistant to the proposed multiple pesticide resistant varieties, would leave us farmers without any known solution according to many weed scientists.

Anyone who has any experience with dicamba has witnessed its volatility. We are not talking about pesticide drift in this context. I have seen dicamba rise from fields and move across the ground damaging any and all vegetables, soybeans, fruit plants, flowers and gardens in its path. Dicamba is not widely used by farmers today for this reason. Even so, as recently as 2008 I had over twenty acre's of tomato's destroyed by dicamba drift. Genetically engineering crops that are resistant to these pesticides must not be approved.

Some would argue that it is not government's role to "stifle innovation" by regulating the commercialization of these crops. But can we trust industry to regulate itself? The history of the American farmer shows that the answer to that question is a resounding NO. If industry cannot be trusted to regulate itself, then who will step up to protect the interests of farmers and the future of agriculture in this country? It is USDA's job to regulate the biotechnology industry.

The time for rubber stamping all that is new, bright and shiny in agriculture is over. We are at a crossroads. Balanced and objective regulation is necessary. And we cannot afford for government policy to be simply cheerlead from behind unexamined commercialization of this herbicide-resistant technology. The future of American farming is at stake and should not be jeopardized simply so a few agrochemical corporations can reap increased profits from the sale of their herbicides.

Thanks you for the opportunity to testify before the Committee. That concludes my Statement and I would be happy to answer any questions that the Chair or the Committee may have.

Mr. KUCINICH. I thank the gentleman for testifying. You will get an opportunity to get into more of this during questions and answers. As I said, your entire testimony will be included in the record of the hearing. We very much appreciate your being here.

The Chair recognizes Professor Owen. Thank you.

STATEMENT OF MICHEAL D.K. OWEN

Mr. OWEN. Good afternoon, Mr. Chairman and members of the committee. Thank you for the opportunity to speak with you today about the economic and environmental effects of the current management of genetically engineered herbicide-resistant crops in the U.S. agriculture.

I served as a member, as noted, of the Committee on the Impact of Biotechnology on Farm Level Economics and Sustainabilty of the National Research Council. The Research Council is the operating arm of the National Academy of Sciences, the National Academy of Engineering and the Institute of Medicine of the National Academies chartered by Congress in 1863 to advise Government on matters of science and technology.

Genetically engineered crops [GE], with resistance to herbicides, were introduced in 1996. In 2010, U.S. farmers grew cultivars of soybean, cotton, corn, canola, and sugar beet with genetically engineered resistance to the herbicide glyphosate. Most herbicide-resistant crops in the United States are resistant to glyphosate, so I will restrict my remarks to this particular trait. I will focus primarily on experiences with herbicide-resistant weeds and soybean, cotton and corn production, as these crops are grown on roughly half of the U.S. crop land.

It should be noted that weeds represent the most economically damaging pest complex to agriculture and are ubiquitous to all agriculture systems. Crops with resistance to glyphosate have been widely adopted by growers. With the adoption of these crops, farmers have substituted the use of glyphosate for other herbicides and weed management tactics, because the resistance allows these crops to survive glyphosate unharmed.

The adoption of glyphosate-resistant crops facilitated production practices such as using no tillage practices. Less tillage can improve soil structure and quality, as well as reduce soil erosion, which enhances water quality. The use of glyphosate in a properly managed herbicide-resistant crop system is an efficient weed management practice. However, management decisions have resulted in increased and often exclusive reliance on glyphosate to manage weeds in GE crop systems and are reducing its effectiveness in some situations due to the evolved resistance to glyphosate in some weed species.

Ten weed species in the United States have evolved resistance to glyphosate since the introduction of glyphosate-resistant crops in 1996. Glyphosate-resistant crops are effectively benign in the environment. Gene flow between herbicide-resistant crops and closely related weed species does not explain the evolution of resistance in U.S. fields, because sexually compatible weeds are absent where corn, cotton and soybean are grown.

Herbicide resistant weeds have historically been a problem in corn, cotton and soybean. Herbicide resistance is not unique to fields with genetically engineered crops. Weeds with either evolved resistance or natural tolerance will proliferate in any field in which the practices are used recurrently and ultimately provide the weed with an ecological advantage.

The concern with glyphosate-resistant crops is that the decision to use glyphosate year in and year out is accelerating the evolution of resistant weeds. Growers are already seeing the economic consequences from the proliferation of these resistant weeds. In Delaware, a study showed that glyphosate-resistant horseweed increased most soybean growers costs by at least $2 per acre. And in a study of 400 corn, soybean and cotton producers from 17 States, growers estimated that glyphosate-resistant weeds increased their costs by $14 to $16 per acre.

To deal with weed problems in these fields, most growers responded that they would increase the frequency of glyphosate applications, they would apply herbicides with different modes of action and increase tillage. The willingness to increase costs to supplement weed management tactics and herbicide-resistant crops indicates that growers value the convenience and simplicity of these crops without appreciating the long-term ecological and economic risks.

Growers must adopt more diversified weed management practices, recognize the importance of understanding the biology of the cropping systems, and give appropriate consideration to more sustainable weed management programs to maintain the effectiveness of the genetically engineer herbicide-resistant crops.

Most of the economically important glyphosate-resistant weeds are found in crop fields in the Southeast and Midwest, and the number of weed species evolving resistance to glyphosate is growing, and the number of locations with glyphosate-resistant weeds is increasing at a greater rate as the decision to spray more acreage with glyphosate continues.

In summary, though the problems of evolved resistance and weed shifts are not unique to herbicide-resistant crops, their occurrence diminishes the effectiveness of weed control practice that has minimal environmental impact. Weed resistance to glyphosate may cause farmers to return to tillage as a weed management tool and to use alternative registered herbicides with different environmental characteristics.

A number of new genetically engineered herbicide-resistant varieties are currently under development and may provide growers with other weed management options when fully commercialized. However, the sustainabilty of these new GE crops will also be a function of how the traits are managed. If they are managed in the same fashion as the current glyphosate-resistant crops, the same problems of evolved herbicide-resistance and weed shifts will occur. Therefore, farmers of herbicide-resistant crops should incorporate more diverse weed management practices. These practices should be encouraged through collaborative efforts by Federal and State government agencies, private sector technology developers, universities and farmer organizations to develop cost-effective resistant management programs and practices that preserve effective weed control in herbicide-resistant crops.

I invite the committee to read my submitted statement and the National Research Council's recent report, The Impact of Genetically Engineered Crops on Farm Sustainabilty in the United States, for greater detail on this topic than I have had time to present today. Thank you.

[The prepared statement of Mr. Owen follows:]

Herbicide-Resistant Weeds in Genetically Engineered Crops

Statement of

Micheal D.K. Owen, Ph.D.
Professor of Agronomy
Iowa State University

and

Member, Committee on the Impact of Biotechnology on
Farm-Level Economics and Sustainability
Board on Agriculture and Natural Resources
Division on Earth and Life Studies
National Research Council
The National Academies

before the

Subcommittee on Domestic Policy
Committee on Oversight and Government Reform
U.S. House of Representatives

July 28, 2010

Good afternoon, Mr. Chairman and members of the Committee, and thank you for the opportunity to speak with you today about the economic and environmental effects of the current management of genetically engineered, herbicide-resistant crops in U.S. agriculture. My name is Micheal Owen. I am associate chair and extension weed scientist in the Department of Agronomy at Iowa State University and served as a member of the Committee on the Impact of Biotechnology on Farm-Level Economics and Sustainability of the National Research Council. The Research Council is the operating arm of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine of the National Academies, chartered by Congress in 1863 to advise the government on matters of science and technology.

Genetically engineered, or GE, crops with resistance to herbicides were introduced in 1996. In 2010, U.S. farmers grew cultivars of soybean, cotton, corn, canola, alfalfa, and sugar beet with genetically engineered resistance to the herbicide glyphosate. Glyphosate is a broad-spectrum, systemic herbicide originally developed and patented by Monsanto and sold under the name Roundup. Though crops have been commercialized with resistance to other herbicides, nearly all genetically engineered, herbicide-resistant crops produced in the United States are resistant to glyphosate, so I will restrict my remarks to this particular trait. I will focus primarily on experiences with herbicide-resistant weeds in soybean, cotton, and corn production as these crops are grown on roughly half of U.S. cropland. It should be noted that weeds represent the most economically-damaging pest complex to agriculture and are ubiquitous to all agricultural systems.

Crops with resistance to glyphosate have been widely adopted by U.S. farmers. In 2010, glyphosate-resistant varieties were grown on approximately 93 percent of soybean acres, 78 percent of upland cotton acres, and 70 percent of corn acres in the United States. As these varieties were adopted, farmers generally substituted the use of glyphosate for other herbicides and weed-management tactics because the GE trait allows these crops to survive glyphosate unharmed (Figures 1–3). The adoption of glyphosate-resistant crops facilitated production success when using no tillage practices. Less tillage can reduce farmers' expenses in terms of time in the field and wear and tear on machinery, and it can improve soil structure and quality as well as reduce soil erosion, which enhances water quality. Because it binds to the soil rapidly, is biodegraded by soil bacteria, and has a very low toxicity to mammals, birds, and fish, glyphosate kills most plants without substantial adverse environmental effects on animals or soil or water quality. The widespread adoption of glyphosate-resistant crops has therefore reduced the use of more toxic (albeit EPA-registered) herbicides in soybean, cotton, and corn fields. However, though fewer types of herbicides have been sprayed since the adoption of glyphosate-resistant crops, the overall amounts of active ingredient[1] in herbicides has not necessarily decreased. Glyphosate is frequently applied in higher doses and with greater frequency than the herbicides it replaced. Thus, the actual amount of active ingredient applied per acre increased from 1996 to 2007 in soybean and cotton but decreased over the same period in corn.

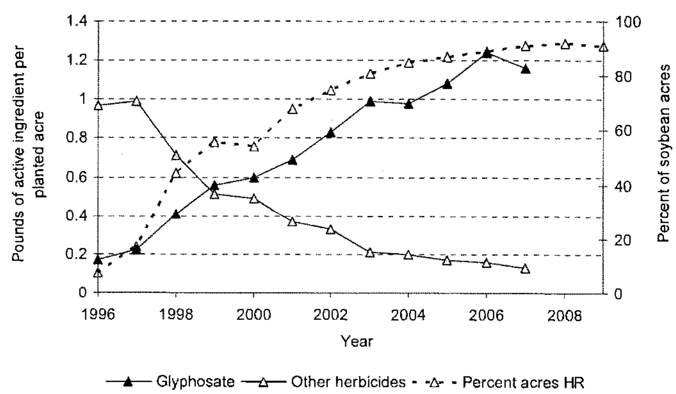

Figure 1. Application of herbicide to soybean and percentage of acres of herbicide-resistant soybean.
Note: The strong correlation between the rising percentage of herbicide-resistant soybean acres planted over time, the increased applications of glyphosate, and the decreased use of other herbicides suggests but does not confirm causation between these variables.
Source: USDA-NASS, 2001, 2003, 2005, 2007, 2009a, 2009b; Fernandez-Cornejo et al., 2009.

[1]The *active ingredient* is the material in the pesticide that is biologically active. The active ingredient is typically mixed with other materials to improve the pesticide's handling, storage, and application properties.

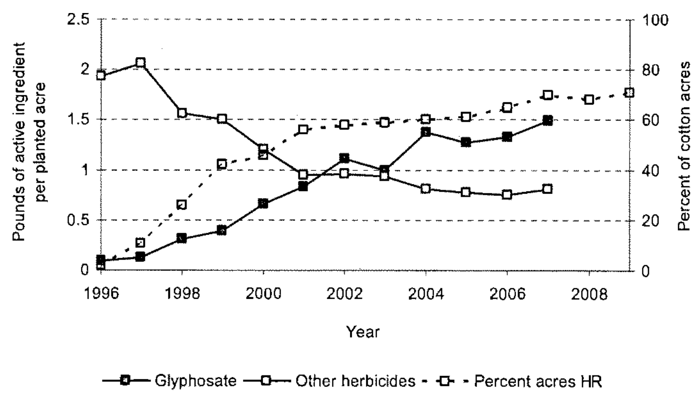

Figure 2. Application of herbicide to soybean and percentage of acres of herbicide-resistant cotton.
Note: The strong correlation between the rising percentage of herbicide-resistant cotton acres planted over time, the increased applications of glyphosate, and the decreased use of other herbicides suggests but does not confirm causation between these variables.
Source: USDA-NASS, 2001, 2003, 2005, 2007, 2009a, 2009b; Fernandez-Cornejo et al., 2009.

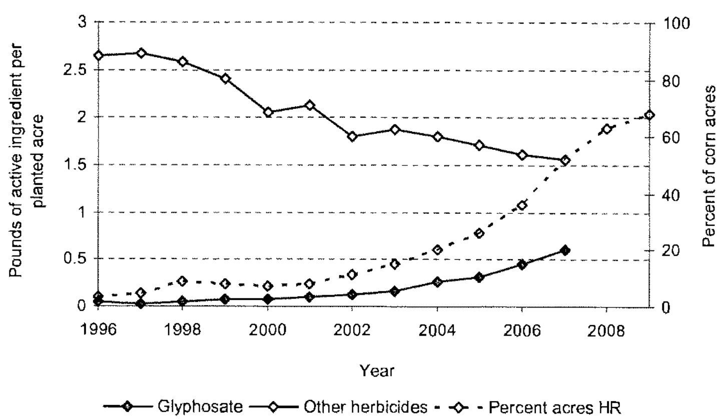

Figure 3. Application of herbicide to soybean and percentage of acres of herbicide-resistant corn.
Note: The strong correlation between the rising percentage of herbicide-resistant corn acres planted over time, the increased applications of glyphosate, and the decreased use of other herbicides suggests but does not confirm causation between these variables.
Source: USDA-NASS, 2001, 2003, 2005, 2007, 2009a, 2009b; Fernandez-Cornejo et al., 2009.

The use of glyphosate in properly managed herbicide-resistant cropping systems is an efficient weed-management practice. However, management decisions have resulted in increased and often exclusive reliance on glyphosate to manage weeds in GE-crop systems and are reducing its effectiveness in some situations due to evolved resistance to glyphosate in some weed species. Glyphosate-resistant weeds have evolved where repeated applications of glyphosate have constituted the only weed-management tactic. Ten weed species in the United States have evolved resistance to glyphosate since the introduction of glyphosate-resistant crops in 1996 compared with seven that have evolved resistance to glyphosate worldwide in areas not growing GE crops since glyphosate was commercialized in 1974 (Figure 4, Table 1). Currently, a total of 19 weeds have evolved resistance to glyphosate worldwide.

Glyphosate-resistant crops are effectively benign in the environment. Gene flow between herbicide-resistant crops and closely related weed species does not explain the evolution of glyphosate resistance in U.S. fields because sexually compatible weeds are absent where corn, cotton, and soybean are grown in the United States. Furthermore, weeds less susceptible to glyphosate are becoming established in some fields planted with herbicide-resistant crops, particularly fields that are treated only with glyphosate (Table 2).

Herbicide-resistant weeds have historically been a problem in corn, cotton, and soybean, and weeds with herbicide resistance are not unique to fields with GE crops. Weeds with either evolved resistance or natural tolerance will proliferate in any field in which the practices are used recurrently and ultimately provide the weed with an ecological advantage. For example, the planting of the same crop year after year or the unvaried use of an herbicide will select for weeds that thrive in those conditions. The concern with glyphosate-resistant crops is that the decision to use glyphosate in every season is accelerating the evolution of weeds with resistance. Because glyphosate-resistant crops are often grown in no-till systems, weeds with resistance are not disturbed by tillage and therefore have a further opportunity to thrive.

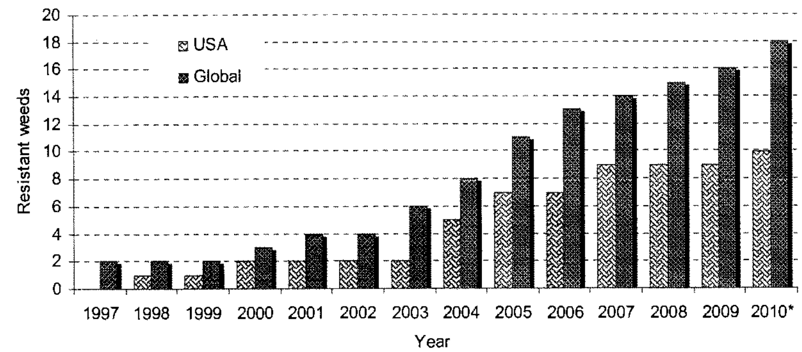

Figure 4. Number of weeds with evolved glyphosate resistance.
*Weed numbers are updated through March 2010.
Source: Adapted from Heap, 2010.

Table 1 Weeds That Evolved Resistance to Glyphosate in Glyphosate-Resistant Crops in the United States

Species	Crop	Location	Acreage[a]
Amaranthus palmeri (Palmer amaranth)	Corn, cotton, soybean	Georgia, North Carolina, Arkansas, Tennessee, Mississippi	200,000–2,000,000
Amaranthus tuberculatus (waterhemp)	Corn, soybean	Missouri, Illinois, Kansas, Minnesota	1,200–11,000
Ambrosia artemisiifolia (common ragweed)	Soybean	Arkansas, Missouri, Kansas	<150
Ambrosia trifida (giant ragweed)	Cotton, soybean	Ohio, Arkansas, Indiana, Kansas, Minnesota, Tennessee	2,000–12,000
Conyza canadensis (horseweed)	Corn, cotton, soybean	14 states	>2,000,000
Kochia scoparia (kochia)	Corn, soybean	Kansas	51-100
Lolium multiflorum (Italian ryegrass)	Cotton, soybean	Mississippi	1000–10,000
Sorghum halepense (Johnsongrass)	Soybean	Arkansas	Unknown

[a]Minimum and maximum acreages are based on expert judgments provided for each state. The estimates were summed and rounded to provide an assessment of the minimum and maximum acreages in the United States. These values indicate orders of magnitudes but do not provide precise information on abundance of resistant weeds.
Source: Data from Heap, 2010.

Table 2 Weeds Reported to Have Increased in Abundance in Glyphosate-Resistant Crops

Species	Crop	Location	Reference
Acalypha spp. (copperleaf)	Soybean	—	Owen and Zelaya, 2005; Culpepper, 2006
Amaranthus tuberculatus (waterhemp)	Soybean	—	Owen and Zelaya, 2005
Amaranthus palmeri (Palmer amaranth)	Cotton	—	Culpepper, 2006
Annual grasses	Cotton	—	Culpepper, 2006
Chenopodium album (common lambsquarters)	Soybean	Iowa, Minnesota	Owen, 2008
Commelina communis (Asiatic dayflower)	Cotton, soybean	Midwest, Midsouth, Southeast	Owen and Zelaya, 2005; Culpepper, 2006; Owen, 2008
Commelina benghalensis (tropical spiderwort)	Cotton	Southeast, Georgia	Owen, 2008; Mueller et al., 2005
Cyperus spp. (nutsedge)	Cotton	—	Culpepper, 2006
Equisetum arvense (field horsetail)	Herbicide-resistant crops	—	Owen, 2008
Oenothera biennis (evening primrose)	Herbicide-resistant crops	Iowa	Owen, 2008
Oenothera laciniata (cutleaf evening primrose)	Soybean	—	Culpepper, 2006
Pastinaca sativa (wild parsnip)	Herbicide-resistant crops	Iowa	Owen, 2008
Phytolacca americana (pokeweed)	Herbicide-resistant crops	—	Owen, 2008
Ipomoea spp. (annual morning glory)	Cotton	—	Culpepper, 2006

Growers are already seeing economic consequences from the proliferation of glyphosate-resistant weeds. In Delaware, resistant horseweed has been documented since 2000, and one study showed this increased most soybean growers' costs by at least $2/acre. In a study of 400 corn, soybean, and cotton producers in 17 states, growers estimated that glyphosate-resistant weeds increased their costs by $14-16/acre. To deal with weed problems in these fields, most growers responded that they would increase the frequency of glyphosate applications, apply herbicides with a different mode of action, and increase tillage.

The willingness to increase costs to supplement weed-management tactics in herbicide-resistant crops indicates that growers value the convenience and simplicity of these crops without appreciating the long-term ecological and economic risks attributable to the unvaried tactics they used. That behavioral response might be expected given many farmers' desire to meet short-run financial needs and the fact that other growers may not take similar control actions. However, growers must adopt more diversified weed-management practices, recognize the importance of understanding the biology of the crop system, and give appropriate consideration to more sustainable weed-management programs to maintain the effectiveness of genetically engineered, herbicide-resistant crops. Furthermore, unless growers collectively adopt more diverse weed-management practices, individual farmer's actions will fail to delay herbicide resistance to glyphosate because the resistant genes in weeds easily cross farm boundaries.

The evolution of glyphosate-resistant or tolerant weeds in GE-crop fields could lead to two important changes in practices: use of different herbicides more widely and reductions in conservation tillage. Such changes would increase weed-management costs and reduce producers' profits and could negate some of the environmental benefits to soil and water quality previously achieved. Most glyphosate-resistant weeds of economic importance in row crops are grown in the Southeast and Midwest. The number of weed species evolving resistance to glyphosate is growing, and the number of locations with glyphosate-resistant weeds is increasing at a greater rate, as the decision to spray more acreage with glyphosate continues. Though the number of weeds with resistance to glyphosate is still small compared to other common herbicides,[2] the shift toward glyphosate-resistant weeds will probably become an even more important component of row-crop agriculture unless production practices (such as recurrent use of glyphosate) change dramatically.

The good news is that there are many strategies that can be used to maintain the effectiveness of glyphosate and sustain the glyphosate-resistant crop cultivars. Tank-mixes and

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[2]For example, 38 weeds have developed resistance to some acetyl-CoA carboxylase (ACCase), and resistance to some acetolactate synthase (ALS) inhibitors has been documented in 107 worldwide.

sequences of herbicides could extend the useful life of herbicides. The development of crop cultivars resistant to two or more herbicides would also be useful. Rotating crops and using alternative weed management systems is another strategy. The increasingly common practice of farmers using glyphosate as the primary or only weed-management tactic in rotations of different glyphosate-resistant crops limits the application of the rotation strategy, but if crops can resist more than one herbicide or if varieties of the same crop are developed with resistance to different herbicides, then rotation could be an option. For example, varieties of GE canola grown in Canada have resistance to the herbicide glufosinate while others are resistant to glyphosate. That variation allows producers to include two types of GE canola into a canola–wheat–barley rotation so that canola resistant to glufosinate or glyphosate would be grown only once every 4 years in a particular field. The reduced exposure to the herbicide slows the evolution of resistant weeds.

From the point of view of herbicide-resistance management and the long-term efficacy of GE herbicide-resistant crops, it may be better to engineer a crop for resistance to herbicides that can efficiently control most weeds associated with the crop. If crops that are resistant to multiple herbicides—including ALS inhibitors, ACCase inhibitors, synthetic auxins, and glyphosate—are widely planted, continued use of the herbicides in fields that contain weeds already resistant to some of them could involve a risk of selecting for high levels of multiple herbicide resistance. The ability of weeds to evolve multiple herbicide resistance has already been demonstrated in waterhemp populations in Illinois, Iowa, and Missouri that are resistant to three herbicide mechanisms of action. Evolved multiple resistance will exacerbate problems of controlling some key herbicide-resistant weeds.

In summary, weed problems in fields of GE glyphosate-resistant crops will become more common as weeds evolve resistance to glyphosate or weed communities less susceptible to glyphosate become established in areas treated exclusively with that herbicide. Though problems of evolved resistance and weed shifts are not unique to these crops, their occurrence diminishes the effectiveness of a weed-control practice that has minimal environmental impacts. Weed resistance to glyphosate may cause farmers to return to tillage as a weed-management tool and to the use of alternative registered herbicides with different environmental characteristics. A number of new genetically engineered, herbicide-resistant varieties are currently under development and may provide growers with other weed management options when fully commercialized. However, the sustainability of those new GE crops will also be a function of how the traits are managed. If they are managed in the same fashion as the current glyphosate-resistant crops, the same problems of evolved herbicide resistance and weed shifts will occur. Therefore, farmers of herbicide-resistant crops should incorporate more diverse management practices, such as herbicide rotation, herbicide application sequences, and tank-mixes of more than one herbicide; herbicides with different modes of action, methods of application, and persistence; crop rotation; cultural and mechanical control practices; and equipment-cleaning and harvesting practices that minimize the dispersal of herbicide-resistant weeds. Such practices should be encouraged through collaborative efforts by federal and state government agencies, private-sector technology developers, universities, and farmer organizations to develop cost-effective resistant-management programs and practices that preserve effective weed control in herbicide-resistant crops.

I invite the committee to read the National Research Council's recent report, *The Impact of Genetically Engineered Crops on Farm Sustainability in the United States*, for greater detail on this topic than I have had time to present today. Thank you for your time.

Mr. KUCINICH. Thank you very much.

Professor Weller.

STATEMENT OF STEPHEN C. WELLER

Mr. WELLER. Thank you, Chairman Kucinich and members of the committee, for inviting me to be a witness today before the Domestic Policy Subcommittee of the Oversight and Government Reform Committee.

I am going to quickly summarize my written testimony and I want to mention that in addition to the written testimony, there is an appendix of a paper that contains much more detail than some of that testimony includes.

Basically, I am here today to provide testimony relating to the issues before this committee as stated in the invitation letter involving genetically engineered herbicide-resistant crops and the environmental impact of the evolution of herbicide-resistant weeds. Additionally, I have been asked to provide testimony on the relationship between adoption of genetically engineered herbicide-resistant crops and the evolution of herbicide-resistant weeds, the rapidity with which certain economically significant weeds have evolved their herbicide resistance, the incidence, risk and implications for farming and herbicide usage of multiple-herbicide resistance in weeds and economic and other consequences for farming and farming practices caused by the evolution of herbicide-resistant weeds.

I will do my best, related to my area of expertise in weed science, to address any questions that are asked of me in addition to my written testimony.

I feel the issues we face in this regard include the overriding issues of the need to farm in a manner that allows high productivity capacity of quality and nutritious food in a manner that minimizes negative environmental impacts, farming that is sustainable for the long term and is acceptable to society.

In a broader sense, all farmers face the challenge of managing pests and the introduction of genetically engineered herbicide-resistant crops was a response to this in regard to weeds. The question before us today is whether these crops have made herbicide resistance in weeds such a problem that we have selected for what some people call superweeds, or what I say, weeds resistant to a particular herbicide or resistant to more than one herbicide.

The basis of my written testimony addresses the following issues: the positive impact that glyphosate-resistant crop plants and the use of glyphosate for weed management has had on improving global production efficiency by providing effective management of weeds. Second glyphosate-resistant weeds are evolving within the eco-agrosystem by adapting to high selection pressures imposed by crop production practices, which is no different than with conventional crops and with other herbicides.

Third, the impact of glyphosate-resistant crops on weed communities is not directly attributed to the use of the crop, but rather an indirect effect of the grower management of the crops and weeds.

Fourth, the rapid adoption of genetically engineered glyphosate-resistant crops occurred because glyphosate effectively controls most of the economically important weeds and simplifies weed management tactics, resulting in both increase of income and other benefits to the grower. The widespread use of genetically engineered glyphosate-resistant technology has facilitated greater adoption of no-till systems that conserve soil and energy resources and reduce environmental impacts, as well as improve the time management for farmers.

Sixth, the widespread adoption of genetically engineered glyphosate-resistant crops has resulted in the grower deciding to simplify weed management to the applications of only glyphosate in many instances. This weed management approach results in imposing considerable selection pressure on weed communities.

However, in recent years, grower awareness for the need for appropriate management tactics, integrated tactics that have been developed over the last 60 years by weed scientists in association with farmers has increased and growers are moving toward a better understanding of the implications of their herbicide use practices in order to improve sustainabilty of the system.

Seventh, glyphosate-resistant weed populations can be and are effectively managed by using other herbicides and/or changing cultural practices. I feel the issues as stated will be supported by much of the testimony we hear before this committee. The adoption of glyphosate-resistant cropping systems has changed agriculture weed management, long-term sustainability based on better weed control, better use of resources, dramatic increases in no-till agriculture, to the benefit of soil conservation and improved safety of water.

The important issue here is not that genetically engineered glyphosate-resistant crops are the cause of herbicide resistance in weeds, but these crops are an additional tool in the array of tools that we have developed over the last 60 years to manage weeds in agriculture. There are challenges to be addressed when these crops are used, but they can be addressed in a proactive manner without jeopardizing this technology.

The key in my mind is related to aggressively meeting the educational and resource challenges necessary to implement sustainable glyphosate-resistant based crop systems. Paramount to meeting this challenge is the need to develop consistent and clearly articulated science-based management recommendations that enable farmers to reduce the potential for herbicide-resistant weeds to evolve, and to understand better the ecology and genetics of these and all weeds.

A proactive, integrated and well-funded educational and research based approach to better manage weeds in all crops, including genetically engineered glyphosate-resistant crops, can minimize the widespread evolution of glyphosate-resistant weeds and weeds resistant to other herbicides and the result and potential loss of these technologies.

Thank you, Mr. Chairman and members of the committee, for offering me the opportunity to speak before you today.

[The prepared statement of Mr. Weller follows:]

Transcript of the testimony of Dr. Dr. Stephen C. Weller, professor, Purdue University to the Domestic Policy subcommittee of the Oversight and Government reform Committee, July 28, 2010.

This transcript and the thoughts herein are in large part based on the manuscript: **Benchmark Study: Perspectives on Genetically-Engineered Glyphosate-Resistant Crops and the Sustainability**
Of Glyphosate-based Weed Management authored by Micheal DK Owen Iowa State University, Bryan G Young Southern Illinois University, David R Shaw Mississippi State University, Robert G Wilson University of Nebraska, David L Jordan North Carolina State University, Philip M Dixon Iowa State University and Stephen C Weller, Purdue University. This manuscript is presently in review for publication and is attached as **appendix I** to this document.

The issues before this committee involve genetically engineered, herbicide resistant crops and the environmental impact of the evolution of herbicide resistant weeds. I have been asked to provide testimony on the relationship between adoption of genetically- engineered herbicide resistant crops and the evolution of herbicide resistant weeds; the rapidity with which certain economically significant weeds have evolved their herbicide resistance, the incidence, risk and implications for farming and herbicide usage of multiple herbicide resistance in weeds; and the economic and other consequences for farming and farming practices caused by the evolution of herbicide resistance in weeds. I will do my best related to my area of expertise in weed science.

There is and always has been a need to farm in a manner that allows high production capacity of quality and nutritious food and to farm in a manner that minimizes negative environmental impacts, is sustainable for the long-term and is acceptable to society.
The widespread adoption of genetically engineered (GE) and glyphosate resistant (GR) or GE GR crops on the agroecosystem and for society has been a contentious topic of debate in scientific journals and the popular media. While adopters of GE GR crops experience pecuniary and non-pecuniary benefits such as highly reduced effort needed to implement a weed management system that significantly increases crop production, the risks as perceived by society, must also be given serious consideration. Complexity of assessing benefits and risks of GE GR crops is great and results can demonstrate considerable variability depending on the specific GE cultivar, the production practices and the specific agroecosystem. Below I will summarize and discuss these issues in regard to GE GR crops and their effects with particular attention to the evolution of glyphosate resistant weeds.

Key points relating to GE GR crops.

1. **One of the keys to improved global crop production efficiency is the effective management of weeds.** Global demands to produce more food have increased dramatically in a relatively short period of time and the ever-increasing global population has placed incredible demands on agriculture to produce sufficient yields. Ideally, increased yield will be achieved through sustainable but intensive production practices that allow dramatic increases in food while protecting aquatic and terrestrial ecosystems. There are only two possible solutions in the immediate

future to the dilemma of increasing requirements for food, biologically-based fuel and fiber; improve production efficiency on existing arable land or increase the land area under cultivation. These two options have both benefits and risks that must be addressed. Improved efficiency on land already under cultivation represents the best option but does not represent a simple means to an end. A longer term solutions to the global demands on agricultural production may be to improve crop genetic yield potentials, responses to stress and increased resources utilization efficiency. Genetically engineered (GE) crops are suggested to be an important tool that will allow improved yields and more efficient use of resources thus enhancing crop production efficiency while minimizing risks to the environment (e.g. soil erosion).

Weeds are constantly evolving within the agroecosystem by adapting to high selection pressures imposed by crop production practices and importantly, evolved resistance to herbicides. While eradication of weeds represents the obvious way to eliminate some crop yield loss, the probabilities of accomplishing this goal are extremely unlikely given the ecological adaptability of plant species to fill niches created by agriculture, and the resource and technical issues that affect weed eradication.

2. **GE-GR crops are an important tool to facilitate better weed management and improve yield and allows more efficient use of resources while minimizing risks to the environment.**
3. **Rapid adoption of GE GR crops occurred because glyphosate controls most of the economically important weeds and simplifies weed management tactics.**
4. **Widespread GE-GR technology has facilitated widespread adoption of no-till systems that conserve soil and energy resources as well as improved time management for farmers.**
5. **However, the widespread adoption of GE GR crops resulted in the grower decision to simplify weed management to the applications of glyphosate imposed considerable selection pressure on weed communities which predictably resulted in weed population shifts including the inevitable evolution of weed populations with resistance to glyphosate.**
6. **There are educational and research challenges to implement sustainable GR-based crop systems and paramount is the need to develop consistent and clearly articulated science-based management recommendations that enable farmers to reduce the potential for herbicide-resistant (HR) weeds and to understand better the ecology and genetics of weeds.**

Benefits and Risks Associated with GE GR Crops

Benefits of GR Crops

GR technology has been adopted by farmers with, in most cases, a high level of satisfaction, implying great benefit. Advantages of GR crops include, the simplification of weed control, greater work flexibility and time management, improved success in conservation tillage production systems and favorable economic returns. The environmental impact to GR crops and glyphosate is favorable compared to "conventional" crop production systems (those using non-GR crops), specifically when soil erosion and water quality are considered. Conservation tillage systems, particularly no tillage systems, are more sustainable and environmentally benign, based on the potential for soil erosion and water quality, than crop production systems based on continuous aggressive tillage and GE GR crops have facilitated more consistent management of weeds in conservation tillage systems, particularly winter annuals that were not previously controlled consistently and effectively. Furthermore, conservation tillage has concomitant benefits of reduced time required to produce crops, reduced use of petroleum fuels, reduced production of greenhouse gases (as well as enhanced carbon sequestration in no-tillage systems), improved soil biological health, improved soil physical health and reduced soil erosion. Society also experiences these benefits attributable to the adoption of GE GR crops.

The favorable economics of GR crops is a major benefit and an important consideration for growers. Actual production costs and yields will vary depending on the specific crop and may not always favor the GE GR cultivars. When economics are considered at the farm enterprise level, including the non-pecuniary benefits such as time management, simplicity, and environmental improvement, the GE GR cultivars are strongly favored when compared with conventional crop cultivars.

Risks of GE GR crops

From an actual scientific perspective, potential risks associated with cultivation of GE GR crops can include effects on ecosystems such as decreased species biodiversity, weed spectrum shifts, and the likelihood that weeds will evolve resistance to glyphosate if it is the only product used. It is important to recognize that these risks are no different for conventional crops and all herbicides. The risks are driven, in part, by ecological factors (i.e. species biodiversity) but influenced by agricultural practices such as tillage and herbicide use. There is not a clear direct effect of GE GR crops on these ecological changes and it is likely that any effect of GE GR crops is confounded by other agricultural practices (e.g. tillage). However, "traditional" agriculture (non- GE) has significantly impacted biodiversity historically and these effects occurred irrespective of GE GR crops.

Evolved resistance in weeds to glyphosate

A primary concern for the long-term sustainability of the GR crop system is the extent that GR weeds will evolve or GR volunteer crops will become a pervasive weed problem and how utilization of additional tools for their control are incorporated into the system. Importantly, the evolution of resistance to herbicides in weed populations is not unique to glyphosate and was in fact predicted more than forty years prior to the wide-spread adoption of glyphosate . Furthermore, predictions specifically addressing evolved resistance to glyphosate preceded the actual reports from the field. University researchers, government agency officials and private sector life sciences companies agree that widespread adoption of GE GR crops and concomitant weed management practices has and will continue to change the abundance and types of weed species found in agronomic fields. The full implications of these inevitable changes in weed populations are, in part, a function of the current production practices and resulting changes are not ecologically different than changes that have historically occurred in response to other agricultural and weed management tactics. Given the cumulative hectares of GE GR crops that have been planted in the US and the selection pressure imposed upon weed communities by the use of glyphosate, it is understandable that significant changes in the agroecosystem have occurred as the result of adopting GE GR crops and glyphosate as the primary if not sole tactic for weed control. There is now general agreement that evolution (defined here as: changes in genotype frequencies that result from selection pressure on genetic variation within a population of a weed species) of GR weed biotypes was inevitable, although, again some disagreement exists on the ultimate degree and nature of GR weed impact on agricultural practices. Currently 19 weed species have evolved resistance to glyphosate (Appendix 1, Figure 1 and Table 4). Eleven of these species are found in the US and eight of the GR weed biotypes evolved in conjunction with GR crops. Given the widespread adoption of GE GR crops (more than 80 million hectares in the US in 2009) and the use of glyphosate, often as the only herbicide used, it is not surprising that the ecological risk of evolved glyphosate resistance has resulted in an increasing number of GR weeds that are evolving at an increasing rate (Appendix 1, Figure 1).

The first GR weed in row crops identified in the US was horseweed [*Conyza canadensis* (L.) Cronq.], and its appearance was possibly correlated with the cultivation of GR soybeans. Recently other GR weed populations have been reported (Appendix 1, Figure 2 and 3, Table 4). All these weeds are major economic problems in agronomic crops in the corn, cotton and soybean growing regions of the US and the distribution of glyphosate resistance in these weeds is increasing. GR horseweed is now wide-spread throughout much the US cropland.

It is important to recognize that the impact of GE GR technology on weed communities is not directly attributable to the use of a GE GR crop, but rather an indirect effect of the management of the GE GR crop[78, 83] (e.g. how and which herbicide is applied) which is different from other GE crops (i.e. cultivars that include GE *Bt*). Specifically, the trait that confers resistance to glyphosate in crops does not, by itself, impart any selection pressure on the weed community. The selection pressure is imposed by the herbicide and is a factor only when the grower makes the management decision how and when to apply the herbicide. However, *Bt* trait in the GE crop exerts selection on the insect complex continuously. Regardless, the occurrence of evolved resistance to glyphosate in weed communities represents an important and escalating problem in global agroecosystems.

The speed and frequency of evolved glyphosate resistance in weeds likely reflects a lack of grower understanding about the influence that production practices, notably herbicide use, has on the composition of the weed community . A recent grower survey funded by BASF Crop Protection Corp. provided further insight into this problem. The "2010 Weeds to Watch Poll" was distributed online to growers, retailers, distributors and university experts throughout the US. Weeds reported in the survey have either evolved GR populations or are known to be naturally tolerant to glyphosate. Survey responses suggested the primary weeds of concern in GR systems nationwide included common lambsquarters (*Chenopodium album* L.), horseweed, giant ragweed (*Ambrosia trifida* L.), waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer.), morningglory species (*Ipomoea* spp.) and Palmer amaranth (*Amaranthus palmeri* S. Wats.). Overall, respondents reported that glyphosate resistance in weeds was a major concern in GR crop systems.

Another survey conducted by Farm Progress Company for Syngenta Crop Protection Corp. on farmer concerns for GR weeds, specifically GR giant and common ragweed (*Ambrosia artemisiifolia* L.) (Appendix 1, Figure 2 and 3) suggested that grower awareness of the immediacy of the potential for evolved weed resistance to glyphosate was high and the need for appropriate management tactics great.

FARMER STAKEHOLDER IMPACT ON GR CROP SUSTAINABILITY

I was involved in a survey in 2005 that assessed the implications of farmer knowledge and attitudes on weed management in GR crops in US agriculture. Farmers did not have a high level of awareness of the potential risks to the sustainability of the GR crop systems regarding evolved glyphosate resistance. However, changes in the crop systems have occurred since this survey, Notably, the number of weeds with evolved resistance to glyphosate has increased from nine to 19 (not all of this increase is associated with glyphosate use in GR crops) resulting in an escalation in presentations and information to growers about the implications of evolved resistance to glyphosate in weeds on the sustainability of GR systems (i.e. "The Glyphosate, Weeds, and Crops Series" [www.glyphosateweedscrops.org]). A survey of grower attitudes we are now conducting should provide better information whether growers are aware of and implementing changes in management programs. Herbicide-use practices by growers in GR crops have also changed since the 2005 survey was conducted as the use of a soil-applied herbicide(s) that provides residual weed control has increased in GR corn and soybean (Appendix 1, Figure 4 and 5). Other studies have shown that growers are moving towards a better understanding of the implications of their herbicide-use practices and thus improved sustainability for the GE GR crops and glyphosate. However, glyphosate is still the primary if not sole weed management tactic in a number of crop systems.

Considerations and Programs to Ensure Sustainability of Weed Management in GR Crop Systems

There are numerous opinions on the best approach for designing herbicide-based programs for managing weeds and preventing or minimizing the effect of GR weeds. The best method of herbicide resistance management is to have weed-free fields and this is true from a theoretical resistance management perspective but is not really environmentally or economically practical so other management tools (i.e. other herbicides) must be used. Most current GR weeds have evolved a relatively low level of resistance to glyphosate which it has been argued can be overcome by adjusting the rate of glyphosate applied. This approach would require farmers to adjust the glyphosate rate to target those weeds in their field in hopes of managing the evolution of GR weeds. There is no scientific consensus that this approach is valid, and increasing the rate of glyphosate may expedite the evolution of GR weeds where the resistance is controlled by a single partially dominant nuclear gene. By using a herbicide rate (higher) that is discriminatory between susceptible and resistant biotypes, the population will shift towards resistance.

Even though a herbicide rate adjustment approach is easiest and may work to lessen the probabilities of herbicide resistance evolution in some weeds, the most sustainable and effective approach to GR weed management should include several tactics such as applying tank mixtures of herbicides with different mechanisms of action, tillage, crop rotation, and other integrated weed management approaches. Herbicide resistance in a few weed species to various herbicide types has not made herbicide use impractical or uneconomical in modern agriculture for most other widely used herbicide types. The tank-mix approach appears to be favored by many farmers, but care must be used in following technical recommendations and choosing the specific tank-mix herbicides to avoid selecting for resistance of weeds to other herbicides and causing antagonistic interactions between herbicides that result in reduced weed control. Another important recommendation is to use a soil-applied herbicide(s) that provide residual control of the target weeds.

Considerable research to discover genes responsible for conferring resistance to an array of herbicides and then include these genes in crop cultivars by genetic engineering is ongoing. GE crops with resistance to dicamba, glyphosate, glufosinate, 2,4-D, and acetolactate synthase inhibitors are either commercially available or under development. The concept is that the use of GE crops resistant to multiple herbicides may allow better management of the evolution of herbicide resistance in weeds. When considering this approach, proper management of each herbicide that can be used in the crop with multiple herbicide resistance is important. Consider that some weed species have evolved multiple- and cross-resistance to herbicides that are widely used in the US. The specific characteristics demonstrated by some weeds that result in resistance to multiple herbicides and even the specific mechanism(s) of cross-resistance remain largely unknown. Furthermore, there has been no assessment of the actual risk of multiple herbicide resistant GE crops to agroecosystems. Consider that resistance to ALS inhibitor herbicides evolved quicker and more widespread than resistance to glyphosate. The evolution of herbicide resistance in weeds is not the result of GE crops but rather the management decision to use a single mode of herbicide action as the primary or sole tactic to control weeds. Multiple herbicide resistant GE crops will not be any more or less sustainable unless herbicide tactics are used judiciously.

Role of the Framer in Resistance management

Because farmers are the ultimate decision makers for the use and management of herbicide resistance and GE GR crops, it is important to understand their attitudes and perceptions about the likelihood of selecting for weed resistance to glyphosate. Once farmer attitudes are understood, they need to be coupled with science-based knowledge that guides development of farmer educational programs. These educational programs must increase awareness and knowledge of GR weeds, how to minimize their appearance and how to manage glyphosate resistance when it evolves in weed populations. The educational programs must be robust and provide knowledge that allows farmers to clearly consider other concomitant risks associated with GE GR crops including maintaining long-term sustainability of this technology that will be impacted by their management decisions. A greater educational emphasis on appropriate integrated weed management through the application of best management practices (BMPs) in GE GR crops will help farmers choose diverse weed management tactics that will not lead to a catastrophic loss of chemical weed control tools, while still allowing them to optimize their income from the hectare. The programs must provide a basic background of weed ecology and biology as well as fundamental information about how herbicides work and how herbicide resistance evolves. The programs should be delivered at multiple levels; from internet-based modules to local face-to-face discussions to field demonstrations. It is anticipated that these educational programs will be delivered by the public sector and the life-science companies.

FINAL THOUGHTS

The sustainability of managing glyphosate resistance in weeds is now being tested in millions of hectares of cropland globally, although in a non-scientific, uncontrolled manner. The solution to the sustainability of herbicidal weed management in general and specifically, GR weed management in GE GR crops must involve more than finding new herbicides, and developing new herbicide resistant crops. A truly effective and economically and environmentally sustainable strategy will include an integrated systems approach to weed management based on the inclusion of multiple crop improvement and farm management tools that have been developed over the last 60 years, and driven by science-based knowledge. These strategies must be packaged into educational modules that offer reasonable and attractive choices to farmers that result in consistent and effective weed control while reducing selection pressure for herbicide resistance evolution in weeds. The Benchmark Study will provide important information that supports these educational platforms.

Mr. KUCINICH. Thank you.

Professor Mortensen, you may proceed for 5 minutes.

STATEMENT OF DAVID A. MORTENSEN

Mr. MORTENSEN. Thanks also for the invitation to present here today. It is a profoundly meaningful invitation for me, and a first one.

The problem of glyphosate resistance is a real and serious one. I won't repeat some of the things that have been said about the species that have evolved resistance. But it is not just a species count. It is also the area of crop land that is being affected, and the comment that a few bad actors is something that maybe we can address. I think we need to take a look at what the extent of the problem is.

I estimate that the resistance problem has spread to some 10 million to 11 million acres, adding some $1 billion to control costs in the current growing season. These estimates, my estimates, seem conservative when seeing recent reports by agri-chemical manufacturers in the last month that project 38 million acres will be infested by Roundup resistant weeds by 2013, a Syngenta estimate, and half of all weed species will be resistant by 2018, a Bayer scientist.

To put a face on the problem, I would like to turn to a recent Farm Press article that appeared in the Southeast Farm Press, a Georgia newspaper, where a weed scientist that a number of us know indicated that in 2005, the first case of pigweed resistant to glyphosate was confirmed in the middle of Georgia. And it was determined to be occupying about 500 acres. The resistant populations have since spread across 52 counties in the State, infesting more than 1 million acres.

Within the next year or two, Culpepper, the weed scientist, estimates that the entire State, all of the counties, will be infested. Growers went from spending $25 per acre for weed control costs in cotton in the State of Georgia a few years ago to $60 to $100 per acre now. At the end of the article, Culpepper argues that herbicides alone often will not provide adequate control, and that an integrated program must be developed to reduce the amount of palmer amaranth, this pigweed plant, from interfering with cotton growth. He goes on, actually, to indicate the importance of recently adopted cover cropping practices by cotton farmers in Georgia.

What in my opinion is most disconcerting, actually, is the industry's response to the resistance problem. And that response is to make crops resistant to multiple herbicides by inserting new genes that will confer resistance to other active ingredients in addition to the glyphosate resistance.

It is my estimate, and those of colleagues that I have been working on this that conservative estimates of adoption would result in a significant increase in herbicide use in soybean and cotton disturbingly through the use of older, higher-use rate herbicides, like 2,4-D and Dicamba. It is our estimate that if these were adopted, we would see an increase in herbicide use by about 70 percent in soybeans. In the written testimony I give a very detailed accounting of how that figure is arrived at.

Interestingly, if you look in the written record at the 23rd reference of the piece that I wrote by Peterson and Holting, they provide a very detailed accounting of why these herbicides should not be used in wheat that has been applied for being released commercially for resistance to glyphosate to move away from the very herbicides that we are going to be using in soybean and cotton as the justification for approving Roundup resistant wheat.

We were asked also to make any suggestions or recommendations to the committee on what is the Federal Government's role in this. I have five recommendations. The first is that the U.S. Environmental Protection Agency and APHIS should require that registration of new herbicide trans-gene crop combinations explicitly address herbicide-resistance management. It is my view that this is not just another resistance problem, but actually a unique one in a sense that we have incorporated a gene insert for an herbicide specifically. We are continuing to ask for new registrations for new applications for other crops.

No. 2, when a new GE resistance trait allows for an old herbicide, like 2,4-D or Dicamba, to be used in new crops, at new rates and in novel contexts, EPA and APHIS should work in a coordinated way to ensure that a thorough reassessment of the herbicide-active ingredient occurs in the context of its expanded and novel use. This reassessment should include explicit consideration of weed resistance and should be regionally relevant as cropping systems vary across the region and recognize the spatial heterogeneity of fields, farms and crops produced.

Third, limit repeated use of herbicides in ways that select for resistance or that result in increased reliance on greater amounts of herbicide to achieve weed control. It is my view that there are ways that this could be done at the farm level.

Fourth, provide environmental market incentives, possibly through the Farm Bill, to adopt a broader integration of tactics for managing weeds. Increasingly, farmers are adopting cover crops, crop rotations and novel selective methods of cultivation for weed suppression.

And fifth, transgene seed and associated herbicides should, in my view, be taxed and proceeds used to fund and implement research and education aimed at advancing ecologically based integrated weed management. Some of you may be aware that we recently saw a major cut in public funding for weed research. I have been struggling personally to think about ways that can be restored.

Thank you.

[The prepared statement of Mr. Mortensen follows:]

Written Statement
Prepared for the
Domestic Policy Subcommittee of the Oversight and Government Reform Committee by
Dr. David A. Mortensen
Weed Ecologist, Department of Crop and Soil Sciences
The Pennsylvania State University

Background. Weeds more than any other agricultural pest type (than insects and disease for example) are widespread and because they overwinter in the soil their emergence each spring is quite predictable. It is not surprising that weed management is a serious matter for farmers. While weed management almost always comprises several tactics, herbicide use is central and accounts for 70% of all pesticides used in agriculture (1).

Since the mid-1990s, adoption of genetically engineered (GE) crops resistant to the herbicide glyphosate has been widespread and herbicide resistant crops are now grown on over 143 million acres of cropland internationally (2) with 92% of the US soybean crop planted to glyphosate resistant varieties. Genetic engineering makes it possible to take a crop that was formally susceptible to glyphosate and genetically transform it to be resistant to the plant-killing effects of the herbicide. The adoption and widespread use GE herbicide resistant crops has greatly changed how farmers manage weeds, enabling them to rely solely on a single tactic approach to weed management (application of glyphosate). Unfortunately, this single-tactic approach has resulted in an unintended, but not unexpected, problem: a dramatic rise in the number of weed species that are resistant to glyphosate (3) and a concomitant decline in the effectiveness in of glyphosate as a weed management tool (4).

Adoption of genetically-engineered herbicide resistant crops and evolution of herbicide-resistant weeds. Not unexpected, the "massive adoption of transgenic glyphosate-resistant crops has meant excessive reliance on glyphosate for weed control. In evolutionary terms, widespread and persistent glyphosate use without diversity in weed control practices is a strong selection pressure for weeds able to survive glyphosate" (5). This over-reliance on single-tactic management has led pest management scientists to question whether integrated pest management is still practiced in such systems (*see* Is Integrated Pest Management Dead? (6)). During the period since the introduction of glyphosate resistant crops, the number of weedy plant species that have evolved resistance to glyphosate has increased dramatically, from zero in 1995 to 19 in June of 2010 (3). This list includes many of the most problematic weed species, such as common ragweed (*Ambrosia artemisiifolia* L.), horseweed (*Conyza Canadensis* (L.) Cronq.), johnsongrass (*Sorghum halepense* (L.) Pers.), and several of the most common pigweeds (*Amaranthus palmeri* S. Watson and *A. tuberculatus* Moquin-Tandon) many of which are geographically widespread (3,7,8). In practice, the problem of glyphosate resistance goes far beyond a species count. There is no question the number of species evolving resistance to glyphosate is increasing at a steady rate of 1-2 species per year. As the recent PNAS report points out (9), this is a conservative estimate as there is no formal, coordinated monitoring and reporting system in place. More importantly, perhaps, is the dramatic increase in acreage infested with glyphosate resistant weeds. The reported extent of infestation in the U.S. has increased dramatically since just November of 2007, when glyphosate resistant populations of eight weed species were reported on no more than 3,251 sites covering up to 2.4 million acres. In the summer of 2009, glyphosate resistant weeds are reported on as many as 14,262 sites on up to 5.4 million acres, and the most recent summary indicates 30,000 sites infested on up to 11.4 million acres (10). In a period of three years, the number of reported sites infested by glyphosate resistant weeds has increased nine-fold, while the maximum infested acreage increased nearly five-fold. There is reason to believe this trend will continue into the future. Of the 41 reports of resistant biotypes, 32 were reported as expanding in acreage, only two were not expanding, while information was unavailable for seven reports.

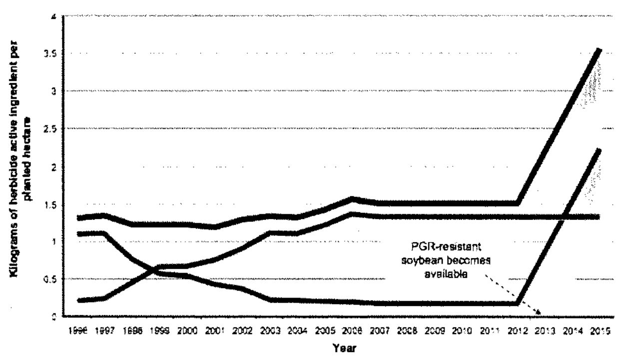
Multiple herbicide resistance. As the recent NRC report on genetically modified crops (9) rightly points out, adoption of glyphosate resistant crops, increasing glyphosate use and reduced tillage are correlated. As tillage is reduced, reliance on herbicides for weed control increases. If glyphosate continues to be used repeatedly within a season and over consecutive seasons, the likelihood for selection of multiple resistance will be high. Resistance can arise from a range of physiological properties of plants from highly specific point mutations to more general physiological processes like enhanced degradation or limited uptake and translocation. Multiple resistance arises when one or several of those processes occur in a plant. For example, *Lolium rigidum* was found to be resistant to glyphosate, paraquat and to ACCase inhibiting herbicides (three unrelated classes of chemistry). While point mutations were the cause of the ACCase resistance and one form of the glyphosate resistance, both glyphosate and paraquat resistance was also attributed to reduced translocation, a much more general physiologic process in plants (11). The fact that more generic physiological processes can work across herbicide modes of action is underscored in the herbicide resistance management section of some herbicide labels. For example, Dow AgroSciences' FirstStep herbicide label (a product containing glyphosate and florasulam, an ALS herbicide) states "FirstStep Herbicide Tank Mix contains a Group 2 and a Group 9 herbicide. Any weed population may contain plants naturally resistant to FirstStep Herbicide Tank Mix and other Group 2 and/or Group 9 herbicides. The resistant biotypes may dominate the weed population if these herbicides are used repeatedly in the same fields. Other resistance mechanisms that are not linked to site of action, but specific for individual chemicals, such as enhanced metabolism, may also exist" (12).

Already, in the Midwest, waterhemp (*Amaranthus tuberculatus*) is resistant to glyphosate and several ALS herbicides (10). While another recent report documents multiple resistance in this species to three unrelated herbicide active ingredients from three distinct modes of action (glyphosate, thifensulfuron, and lactofen)(13).

Economic and other consequences on farming and farming practices caused by the evolution of herbicide resistant weeds. USDA's Agricultural Research Service (ARS) estimates that up to 25% of annual US pest (weed and insect) control expenditures are attributable to pesticide resistance management (14). The cost of forestalling and controlling herbicide-resistant weeds therefore costs farmers approximately .9 billion dollars each year (13% of $7 billion). This cost mirrors the acres infested with glyphosate resistant weeds from the North American Herbicide Resistant Weeds survey (10). If the upper estimate of 11.4 million acres is representative of the spatial extent of glyphosate resistant weeds and those fields are managed at an additional cost of $10-20 per acre and the equivalent of three times that area in close proximity to those fields is also managed to control resistant weeds, then some 45.6 million acres of farmland would be managed at a cost of $.45-.9 billion each year.

In addition to production costs, resistance is manifesting itself in other ways. A worrisome trend is evident in how herbicide and germplasm development companies are responding to the glyphosate resistance problem (15). A new generation of genetically engineered crops are under development where glyphosate resistant cultivars are being engineered to have additional resistance traits introduced into the crop's genome. These additional gene inserts will confer resistance to other herbicide active ingredients, including 2,4-D and dicamba (16-18). For a variety of reasons, it is quite likely that such crops will be widely adopted (15). Conservative estimates of adoption would result in a significant increase in herbicide use in soybean and cotton; disturbingly, through the use of older higher use-rate herbicides. If glyphosate and 2,4-D or dicamba (PGR herbicides) are adopted in the way I expect they will, herbicide use in soybean would increase by an average of 70% in a relatively short time after the release of these new genetically engineered herbicide resistant cultivars (see figure below).

Figure 1. Total herbicide active ingredient applied to soybean in the United States*.



*Data from 1996 to 2007 are from the US Department of Agriculture, National Agricultural Statistics Service; modified from Figure 2-1 In *Impact of Genetically Engineered Crops on Farm Sustainability in the United States*, Committee on the Impact of Biotechnology on Farm-Level Economics and Sustainability; National Research Council, National Academies Press (2010). To forecast herbicide rates from 2008 to 2015 we assumed the acreage of glyphosate-resistant soybean, rates of glyphosate applied and rates of "other herbicides" remained constant at 2007 levels until 2013 (when PGR-resistant soybean varieties are expected to become available). Yearly increases in PGR herbicides (increases in "other herbicides") were calculated by assuming a 33% annual adoption rate of PGR-resistant soybean from 2013-2015 such that by 2015, 92% of U.S. soybeans would be PGR and glyphosate-resistant. We further assume that adoption of PGR herbicide use in soybean would mirror adoption of the resistant soybean. Our estimates encompass low (.57 kg ha^{-1} or .5 lb $acre^{-1}$) and higher (2.24 kg ha^{-1} or 2 lb $acre^{-1}$) use rates; a range in use-rate typical of other PGR tolerant crops (19-20).

Expanded use of these PGR herbicides is unprecedented during this time of the growing season (later and warmer than other uses). Vapor drift of PGR herbicides has been implicated in many incidents of crop injury (17, 21, 22), and may have additional impacts on natural vegetation interspersed in agricultural landscapes. A comparative risk assessment that included glyphosate as a benchmark found the relative risk of non-target terrestrial plant injury was 75 to 400 times higher for dicamba and 2,4-D respectively (23). A growing body of work indicates non-crop vegetation supports important ecosystem services that include pollination and biocontrol (24, 25). Ironically, the comparative risk ecological risk assessment cited above (23) concluded the adoption of glyphosate tolerant wheat would enable farmers to move away from environmentally troublesome herbicides like 2,4-D and dicamba.

Taken together, the herbicide and seed breeding industry is moving to address the problem of resistance with crops that have been engineered to be resistant to multiple herbicide active ingredients. If these new GE crop introductions occur as reported (16-18) we should expect to see herbicide use continue to increase and a significant proportion of those added herbicides will be older, less environmentally benign compounds (23).

The role of federal regulation in forestalling the further development of herbicide-resistant weeds. The following is a list of steps that could significantly improve the sustainability of weed management practices in American agriculture.

1. The U.S. Environmental Protection Agency (EPA) and APHIS should require that registration of new herbicide/transgene crop combinations explicitly address herbicide resistance management (26).

2. When a new GE resistance trait allows for an old herbicide to be used in new crops, at new rates, and in novel contexts, EPA and APHIS should work in a coordinated way to insure that a thorough reassessment of the herbicide active ingredient occurs in the context of its expanded and novel use. This reassessment should include explicit consideration of weed resistance and should be regionally relevant and recognize the spatial heterogeneity of fields, farms, and crops produced (27, 28).

3. Limit repeated use of herbicides in ways that select for resistance or that result in increased reliance on greater amounts of herbicide to achieve weed control. In the same way that Bt is regulated at the farm level, it's entirely feasible to consider farm-level herbicide management planning to limit practices that accelerate herbicide resistance.

4. Provide environmental market incentives (possibly through the farm bill) to adopt a broader integration of tactics for managing weeds. Increasingly, farmers are adopting cover crops, crop rotations and novel selective methods of cultivation for weed suppression.

5. Transgene seed and associated herbicides should be taxed and proceeds used to fund and implement research and education aimed at advancing ecologically-based integrated weed management (IWM).

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Mr. KUCINICH. I thank the gentleman.

Mr. Kimbrell, you may proceed for 5 minutes.

STATEMENT OF ANDREW KIMBRELL

Mr. KIMBRELL. Thank you, Chairman Kucinich, Ranking Member Jordan and the members of the committee and subcommittee, for allowing me to testify today. I am very grateful for that.

I actually think, ironically, and it gets to my testimony, that the discussion today, which is very informative, and I am learning a lot, and I am sure the written statements are probably the, not probably, certainly the greatest investigation of this issue that has yet taken place. And certainly greater than anything done at the USDA or the EPA, to my knowledge. So I thank you for that.

I would argue that what we see before us in this problem that has been described today is not an act of nature, or an act of God, but an act of an agency. That agency that related through acts of omission has caused this problem. That agency is the USDA and specifically APHIS, as you mentioned earlier, Chairman.

I want to just quickly go through, if I could, sort of the litany of what has happened here. In 2005, the IG office audited APHIS' work on GE field trials. The only way you could summarize that report is that APHIS was grossly negligent in providing information and gathering information about those field trials that would be valuable to assess both gene flow and the superweed problem.

Unfortunately, APHIS did not take those recommendations into consideration, and less than 1 year later, Bayer's Liberty Link, from a field trial, from a small field trial, contaminated rice throughout the Southern States of this country, costing farmers over $1 billion, $1 billion, in losses. Now, having numerous lawsuits, class action lawsuits since then against Bayer, the last five that I know of have been successful, but nowhere near recouping that loss.

Because of that, USDA came up with a document called Lessons Learned. Well, they may have been lessons learned, but they weren't lessons that were then executed. As a matter of fact, they implemented none of their own suggestions. Essentially in the 2008 Farm Bill, in the Farm Bill as enacted, were those recommendations saying the USDA, these are your own lessons learned about gathering information, about looking at superweeds, about looking at gene flow, about looking at the economic impacts on farmers. You did none of that. So you have 18 months to do it, 18 months.

And the Farm Bill, of course, it has long since been 18 months, and they have not done any of that.

Then the GAO report came out in 2008, GAO report again said, you are not providing this information on gene flow, you are not protecting farmers, you are not taking any of the steps that you were supposed to. And nothing has happened with those GAO recommendations.

So you have the agency, you have the congressional investigative arm. You have Congress itself in the Farm Bill saying, USDA, get your act together, you are a dysfunctional agency when it comes to biotechnology regulation.

But that is not all. Five different lawsuits, judges that have been appointed by both Republican and Democratic administrations, five in a row have come down and said to USDA-APHIS, and it is in my written testimony, used words like, your approach is absurd, complete disregard for the law, you have abdicated your responsibilities, and this includes bentgrass, field trials, alfalfa, sugar beets and biopharmaceuticals. Five times in a row. And these were unappealed, these parts of the decisions were unappealed.

So we have a rogue agency. And we have an agency that is basically regulating through litigation. The only way they are actually doing any regulation at all is through litigation.

Now, in 2004, they said they were going to do a programmatic Environmental Impact Statement on just the issues that we have heard today. That has never been completed. The courts ordered them to do an Environmental Impact Statement on genetically engineered bentgrass, Roundup Ready. They have not ever done that, completed that. They said to the court in Alfalfa, they would do an Environmental Impact Statement in 2 years. It is now 3½ years. Numerous failed appeals later, and they still haven't done it.

So what is the impact of this? Let's take a look. This is not just, though I am an administrative lawyer, this is not just about administrative law, this has real life impacts as we have heard from the other folks who have testified today, the scientists. We have environmental harms like superweeds and gene flow contamination of organic and conventional crops that are allowed to happen without the protections established by law. And I want to address something Representative Schock said, which is, the whole point of this is to get the information to policymakers and the public and the farmers so they can make those educated decisions. When the USDA fails in that mission, that important information that has been called for by these scientists today is not forthcoming, and scientists and policymakers and farmers cannot make those educated decisions.

Additionally, organic and conventional farmers and businesses relying on these products suffer major economic harm because the laws are not followed. If past is prologue, then StarLink and Bayer will end up costing us billions of dollars, as they have in the past, if this is not remedied at the agency level. Farmers who buy into, and this has happened with alfalfa, there were sugar beets, we were there with bentgrass, some farmers who bought into this, well, USDA approves the product, deregulates the product, some farmers buy into it, then a court declares that approval illegal.

Well, the farmers are holding the bag. Right now, farmers who have GE alfalfa, sugar beets, they are in legal limbo, because courts have declared those crops illegal.

Finally, the businesses themselves, agricultural biotechnology businesses themselves, are facing liability and financial uncertainty. So all of the actors are affected by this agency, this dysfunctional agency that is unfortunately regulated through litigation. I think a major thing we have to do, and perhaps we can discus this later, is how we can through this committee, how we can begin to address this problem.

Thank you.

[The prepared statement of Mr. Kimbrell follows:]

THE CENTER FOR
FOOD SAFETY

HOUSE COMMITTEE ON OVERSIGHT & GOVERNMENT REFORM
SUBCOMMITTEE ON DOMESTIC POLICY

ARE SUPERWEEDS AN OUTGROWTH OF USDA BIOTECHNOLOGY POLICY

STATEMENT OF ANDREW C. KIMBRELL
EXECUTIVE DIRECTOR – CENTER FOR FOOD SAFETY
July 28, 2010

Good Afternoon Chairman Kucinich, Ranking Member Jordan and Members of the House Committee on Oversight and Government Reform, Subcommittee on Domestic Policy.

My name is Andrew C. Kimbrell. I am a public interest attorney and the Executive Director of the Center for Food Safety. I founded the Center over fifteen years ago in order to help protect human health and the environment, curb the proliferation of harmful food production technologies, and promote organic and other forms of sustainable agriculture. CFS is a 501(c)(3) non-profit based here in Washington, DC.

I appreciate the invitation to testify before the Subcommittee. As the other panelists, I'm here today to discuss the glyphosate resistant weed crisis facing U.S. farmers. Equally important and relatedly, I will discuss the concurrent and interconnected failure of the U.S. Department of Agriculture (USDA) to address the negative environmental, agronomic and socioeconomic impacts of agricultural biotechnology using its existing statutory authority.

The history of USDA's oversight of genetically engineered (GE) crops is littered with failures. The Government Accountability Office (GAO), the USDA's own Office of Inspector General (OIG), and the Federal Courts have repeatedly condemned USDA for oversight deficiencies and inadequate management. Regarding the latter, regulation of

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GE crops has in part been defined by judicial decisions in lawsuits brought by CFS and others on behalf of farmers, consumers, and environmental groups. American agriculture cannot afford such "regulation by litigation," an approach that has become standard operating procedure at USDA. I am hopeful that today's hearing will initiate a transformation in agricultural biotechnology oversight that more appropriately balances the interests of the farmer, the environment and the consumer with those of the biotechnology industry.

CFS and its coalition of government watchdogs are not alone in condemning USDA on this issue. Numerous government assessments have found USDA's oversight severely lacking. For example, a 2005 OIG Audit of GE crop field trials revealed frequent cases where the agency did not know the planting locations of field trials, did not require submission of written protocols prior to issuing a permit, did not maintain a list of planted field trials, and, in the case of pharmaceutical crops, failed to conduct scheduled field trials. In two cases, OIG inspectors found two tons of pharmaceutical crops that had been harvested and held in storage for more than one year without APHIS' knowledge and inspection, contrary to permit requirements. As a result of these failures, OIG issued a series of recommendations to strengthen USDA's management and oversight of field trials.

Unfortunately, the OIG recommendations went largely unheeded, and less than one year later, LL601, an unapproved experimental GE rice also known as "Liberty Link rice," contaminated U.S. rice producers. This contamination event cost rice producers and the rice industry more than one billion dollars. Several cases have gone to trial with farmer plaintiffs recovering millions in jury awards. After an internal investigation, USDA concluded that its own mismanagement of field trials was responsible for the Liberty Link rice contamination event. Initial contamination occurred as much as 5 years earlier, going undetected and spreading throughout much of the southern rice producing states. The recommendations for strenthening management and oversight of GE crop field trials identified by USDA as corrective measures, many of which were identical to the recommendations contained in the OIG Audit, were published in a manual entitled Lessons Learned. This USDA manual was later codified in the 2008 Farm Bill amendment sponsored by Sen. Pryor (D– AR) and enacted into law. Despite an 18 month implementation deadline, USDA has still not complied with the statutory mandates.

This arrogance is characteristic of USDA's attitude regarding regulation of biotech crops and its responses to criticism of its regulatory processes. A 2008 GAO Report requested by Senators Harkin and Chambliss, noting the billions of dollars in economic damages associated with GE crop contamination events, concluded that "such contamination events are not isolated incidents, as biotechnology proponents argue. *Rather the ease with which genetic material from crops can be spread makes future releases likely.*" The Report called on the USDA "to monitor for other unintended consequences, such as economic impacts on other agricultural sectors, such as organic crops, which may become contaminated by GE crops." As particularly relevant here, the Report further recommended the mandatory monitoring of resistant weeds, with continuing regulatory authority to mitigate impacts should they arise.

Farmers have long demanded economic injury to be part of the assessment process for GE crop commercialization. USDA has steadfastly maintained that it lacks the statutory authority to make that assessment a part of the deregulation decision-making process. We believe that clear and unequivocal statutory authority exists in the Plant Protection Act (PPA) to consider economic harm to farmers as part of this process. Not only does the statutory authority exist, but the PPA actually confers a mandatory obligation on the Secretary to consider any and all, direct and indirect impacts, including economic harms, to farmers and the agriculture of the United States.

Instead, USDA has self-imposed a very limited interpretation of its regulatory ambit, claiming that once that narrow review is completed, all further oversight or inquiry must end. USDA has repeatedly taken the position that its limited authority precludes assessments of a wide array of environmental impacts stemming from biotech crops – including but not limited to glyphosate resistant weeds – under the PPA, the National Environmental Policy Act, and other environmental laws.

Like the independent governmental reviews, our courts have been forced to repeatedly condemn USDA's failings. For example, in holding that USDA failed to comply with NEPA and the Administrative Procedure Act (APA) in approving Roundup Ready alfalfa, a federal district court concluded that "even though the agency acknowledged that gene transmission could and had occurred with Roundup Ready alfalfa, it *refused* to analyze the likely extent of such gene flow and how it could be eliminated or at least minimized." *Geertson Seed Farms v. Johanns*, 2007 WL 1302981 (N.D. Cal. 2007) (May 3, 2007), at *1. In setting aside the agency's approval of the biotech crop, the same court also held that "APHIS *simply ignored* the concerns of farmers that do not want to grow or feed to their livestock genetically engineered alfalfa." 2007 WL 518624, at *7. These merits findings by the court were not appealed. Another district court concluded in 2006 that USDA's approval of biotech, pharmaceutical-producing plant field trials in Hawaii violated the Endangered Species Act (ESA) with "utter disregard":

> APHIS's utter disregard for this simple investigation requirement, especially given the extraordinary number of endangered and threatened

> plants and animals in Hawaii, constitutes an unequivocal violation of a clear congressional mandate.

Center for Food Safety v. Johanns, 451 F.Supp.2d 1165, 1182 (D. Hawaii 2006). That same court held that USDA's NEPA decision "abdicate[d]" its responsibilities and instead asked for deference to "post hoc rationalizations." *Id.* at 1184-1185.

In another case regarding the field testing of GE Roundup Ready bentgrass, which eventually contaminated a protected national grassland, a court found the record "devoid of *any* evidence" USDA had complied with NEPA, and held the agency's PPA analysis "backwards." *International Center for Technology Assessment v. Johanns* 473 F.Supp.2d 9, 26 & 29 (D.D.C. 2007). Finally, in yet another case, this time concerning Roundup Ready sugar beets, a court held USDA's analysis was not "'convincing' and d[id] not demonstrate the 'hard look' that NEPA requires." *Center for Food Safety v. Vilsack*, 2009 WL 3047227, 9 (N.D. Cal. 2009); *id.* ("To the limited extent APHIS did examine this issue, it did so only on a cursory level. ... Moreover, there is *no support* in the record for APHIS' conclusion that non-trangenic sugar beet will likely still be sold and will be available to those who wish to plant it ....").

I could elaborate on many more examples of the outrage expressed by courts on USDA regulatory failures and deficiencies. The clear picture they draw is of a rogue agency unwilling to comply with its statutory and legal responsibilities.

USDA's unnecessarily cabined view of its regulatory authority is often compounded by the agency's use of questionable facts and faulty assumptions that have no basis in "sound science," as required by the PPA. Glyphosate resistant weed issues exemplify how USDA minimizes significant potential environmental impacts by applying questionable assumptions to randomly selected facts.

Since the first glyphosate resistatn weed populations were confirmed in 1998, 53 populations of 10 different weed species at tens of thousands of sites have evolved glyphosate resistance. Glyphosate resistant weeds now infest an estimated 11.4 million acres. North Carolina Weed Scientist, Alan York, has called glyphosate resistant weeds "potentially the worst threat to cotton since the boll weevil" due to extraordinary levels of dependence on glyphosate.

The December 2009 draft of the court-ordered Environmental Impact Statement (EIS) on Roundup Ready alfalfa – the *first* EIS USDA has ever completed on *any* biotech crop – acknowledges the existence of glyphosate resistant weeds, citing research that has identified 9 glyphosate resistant weeds in the U.S. since 1998, admitting that 8 out of the

14 glyphosate resistant weeds known globally are prevalent in alfalfa stands and, that of the 21 weeds naturally resistant to glyphosate, 10 are problems in alfalfa. Yet despite this acknowledgement, USDA concluded in its draft that, since herbicides are used in alfalfa predominantly during stand establishment with minimal applications after the first year, there is little chance that glyphosate resistant weeds will develop as a result of deregulating RR Alfalfa. What is the sound science basis this conclusion? I find no support in the research or the literature.

Moreover the EIS claims that even if glyphosate resistance is a problem, USDA lacks authority to address it. This conclusion is despite the fact that the epidemic stems from and is exacerbated by the approval of biotech, pesticide-dependent cropping systems. In the original litigation forcing this EIS (again, not appealed) the lower court held USDA's original assessment of weed resistance harm arbitrary and capricious and "cavalier":

> APHIS's reasons for finding the development of glyphosate resistant weeds not to be significant are not convincing. Reasoning that weed species often develop resistance to herbicides is tantamount to concluding that because this environmental impact has occurred in other contexts it cannot be significant. Nothing in NEPA, the relevant regulations, or the case law support such a cavalier response.

2007 WL 518624 (N.D. Cal. 2007) at *10. USDA's current dismissal of the problem unfortunately seems similarly cavalier.

A larger issue looms with respect to glyphosate resistant weeds. Because the industry or government has not undertaken a concerted effort to address the serious and growing threats posed by glyphosate resistant weeds, the standard response has been to switch modes of action through the use of other chemical pesticides in combination with tillage. Increasingly, farmers are forced to return to soil-damaging tillage practices and the use of toxic chemical pesticides that were supposed to have been made extinct through the introduction of glyphosate. Triazines, 2,4D and Dicamba are being tank mixed with glyphosate to eliminate problems with glyophosate resistant weeds. Some glyphosate resistant weeds are beginning to demonstrate a tolerance to other classes of herbicides being tank mixed with glyphosate, namely ALS and PPO inhibitors and triazines. As weed resistance to multiple herbicides grows, industry has begun experimentation with biotech varieties that are genetically engineered to be tolerant to multiple herbicides, including 2,4D and Dicamba. We simply cannot afford to rubber stamp approval of these proposed new GE varieties now in research and development. Weed scientists are cautioning that should weeds develop resistance to these multiple herbicide tolerant varieties, no solution is readily foreseeable. USDA simply cannot afford to continue to abdicate its regulatory responsibilities with these new untested technologies on the horizon.

CFS, on behalf of farmers, environmental and other groups, has filed and prevailed in multiple lawsuits on the appropriate processes and analyses required in USDA's biotech crop oversight. Unfortunately, rather than correct its errors, USDA has thus far repeatedly "doubled down" on them. For example, courts struck down USDA's view that it need not assess potential injury because the harm was not legally cognizable (in cases regarding GE alfalfa and GE bentgrass). USDA then claimed that even if such harm *is* cognizable, the agency *still* need not address such harms, because it lacks authority to address them. A different federal court had already ruled against this argument in another case, concerning GE Roundup Ready sugar beets. *Center for Food Safety v. Vilsack*, No. C 08-00484 JW, 2009 WL 3047227, at *13 n.3 (N.D. Cal. Sept. 21, 2009). The Supreme Court's recent decision in the GE Roundup Ready alfalfa case is also predicated on the conclusion that USDA has the authority to address and regulate transgenic contamination. There, the Court found standing for the Plaintiffs and posited a potential future in which USDA could limit Roundup Ready alfalfa's planting to specific geographic zones to protect against contamination harm. *Monsanto v. Geertson Seed Farms*, ___ S.Ct. ___, 2010 WL 2471057, *11-14, 21 (U.S. June 21, 2010).

USDA's position on weed resistance harm has thus far mirrored its overarching and repeated recidivism. In the face of this growing epidemic, USDA has passed the buck. It is time for change under this new administration. It is past time that USDA adopt a new policy of risk assessment and biotech crop regulation that complies with its statutory mandates. At bare minimum, the USDA must reconcile contradictory policies within the agency. While USDA/APHIS barely acknowledges the existence of glyphosate resistant weeds, USDA/NIFA has determined that "there have been increasing numbers of species and an expanded distribution of the range of broadleaf weeds with resistance to glyphosate" and dedicated Critical Issues: Emerging and New Plant and Animal Pest and Diseases grant program funding to examine herbicide resistance development, economic impacts of glyphosate resistance and current distribution and the risk of expanded herbicide resistance among other weed species in additional cropping systems. While APHIS minimizes the risks, impacts and significance of glyphosate resistant weeds in order to deregulate new GE varieties, its sister agency is expending taxpayer dollars to eradicate the problems created by overuse of the technology.

USDA has also failed to utilize the broad authority conferred in the Plant Protection Act (PPA) over plant pests and noxious weeds. Plant pests are defined broadly to include "substances, which can directly or indirectly injure or cause disease or damage in or to any plants or parts thereof, or any processed, manufactured, or other products of plants."

7 C.F.R. 340.1. The PPA provides significant authority to prohibit or regulate noxious weeds, which again are broadly defined to include "any plant or plant product that can directly or indirectly injure or cause damage to crops (including nursery stock or plant products), livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment." 7 U.S.C. 7702(10). It is implausible and irresponsible to read this legislative language in such a way as to preclude regulation. Yet that is precisely what USDA does.

Congress provided the Secretary of the USDA with expansive powers to protect the vast interests of the U.S. farmer and American agriculture. USDA needs to use the powers available to it to better protect those broad interests, not merely those of the biotech companies which it is charged with regulating. We call on the Secretary to take action to broaden the scope of its regulatory powers through the finalization of the currently halted PPA rule-making and its Programmatic EIS that has languished for over 6 ½ years. That rule-making contemplated a more expansive regulatory implementation, to meet the challenges of new innovations in agricultural biotechnology. We cannot afford to regulate by court order any longer.

I thank the Chair and the Members for the opportunity to testify before the Subcommittee. Should the Members have questions, I would be happy to answer them.

Mr. KUCINICH. I thank all of the gentleman who have testified. As I said, your entire statement will be included in the record of the hearing.

Given the complexities of what you present, the Chair and the ranking member will each have 10 minutes in the first round of questioning, and other Members will have 5. Then if necessary, we will go to a second round of questioning of 5 minutes each.

I want to begin with Dr. Weller. Dr. Weller, you were quoted in a 2001 article about glyphosate-resistant horseweed in the Indianapolis Star as saying, "We thought we had a herbicide that was infallible." I think you were speaking here about Monsanto and many weed scientists who both adored Roundup's effectiveness and misjudged the likelihood of evolving Roundup resistant weeds.

How could so many educated people so profoundly misjudge, and in some cases ignore the law of natural selection?

Mr. WELLER. When the herbicide came out, glyphosate, many people called it a non-selective herbicide. And I think many people bought into this fact that it was non-selective. What I mean by that is, theoretically it would kill all weeds that it was applied to or all plants that it was applied to.

In fact, glyphosate is a very selective herbicide.

Mr. KUCINICH. So it was mislabeled?

Mr. WELLER. I don't think it was mislabeled. I think there were many misconceptions that in agriculture uses, it would be very effective.

Mr. KUCINICH. Let me ask you this. You were quoted in a Farm Press article earlier this year as saying—excuse me, let me go to Dr. Owen. You were quoted in a Farm Press article earlier this year as saying with respect to glyphosate-resistant weeds, "Right now, we are on the edge of a precipice that we could fall off of in the next 2 years."

Could you explain what that precipice is?

Mr. OWENS. What I was referring to is if we continue to use the product and the technology in the manner that historically we have done, we are now at the edge of where the, while the problems in Iowa are relatively infrequent, they are frequent enough that we will quickly move into an area where, I don't want to suggest it would be similar to what the cotton producers in Georgia have experienced, but certainly much greater——

Mr. KUCINICH. Which was what?

Mr. OWENS. With the palmer pigweed and their need to grow cotton without tillage and continue to use glyphosate exclusively, they basically ran themselves out of business.

Mr. KUCINICH. Let me ask you this, Professor Owen, and Professor Mortensen, if you could chime in. Let me read you a comment that was made by Dow AgroScience scientist, John Chichetta, to the Wall Street Journal in an article entitled, "Superweed Outbreak Triggers Arms Race." "It will be a very significant opportunity, it is a new era." What Mr. Chichetta is talking about is that Dow has a new opportunity to sell 2,4-D and a new variety of 2,4-D-tolerant soy, corn and cotton. This opportunity was created by glyphosate resistance in weeds, a development that hurts Monsanto, a competitor.

Now, Professor Owen, isn't it true that Dicamba and 2,4-D are more toxic herbicides than glyphosate?

Mr. OWEN. Based on the EPA regulations, they are considered to be more toxic.

Mr. KUCINICH. And then Professor Mortensen, Mr. Chichetta's comments reveal the biotech industry is betting on farmers using more and more toxic herbicides, isn't that right?

Mr. MORTENSEN. Yes, the quote in the Wall Street Journal, because I was also quoted in the same article, is very disturbing to me, actually. Because I think it just kind of laid it wide open that——

Mr. KUCINICH. Well, let me ask you——

Mr. MORTENSEN [continuing.] Laid open the fact that they are expecting that this is going to open up a whole new area of research and marketing to combat the glyphosate resistance, yes. I don't think there is any question about that.

Mr. KUCINICH. Do you have any estimates of how much more toxic herbicides will be used, Professor Mortensen?

Mr. MORTENSEN. Yes, in that same article I was quoted, and this has been something we have been working on for the last year and a half or so to come up with reasonable estimates, but something like 58 million pounds more——

Mr. KUCINICH. Really?

Mr. MORTENSEN [continuing]. In soybeans alone.

Mr. KUCINICH. You testified that Syngenta's Chuck Forsman predicts that 38 million row crop acres will be infested with glyphosate-resistant weeds by 2013. That is a fourfold increase in just 3 years.

Mr. MORTENSEN. Yes, that is what the quote is. Based on my best estimates from the WSSA, the Weed Science Society of America reporting site, my best estimates are that since 2007 alone, the acreage increase of resistant weeds has increased five-fold.

Mr. KUCINICH. Let me ask you this. Bayer crop scientist Harry Streck cites research suggesting that 50 percent of agricultural weed species will be glyphosate-resistant by 2018. Now, would you say, Professor Mortensen, that these industry predictors constitute what could be described as a catastrophic problem for farmers?

Mr. MORTENSEN. I think it is certainly a very serious problem. No question. It is a very serious problem.

Mr. KUCINICH. And Mr. Roush, the ability of weeds to select for herbicide-resistant traits is not a new thing. Isn't it true that the recent commercialization of crops genetically engineered to be tolerant of certain herbicides has aggravated that problem, precisely because farmers can apply types of herbicide to their land that normally would have killed the crop as well as the intended target, the weed?

Mr. ROUSH. What it has done is, glyphosate is very cheap.

Mr. KUCINICH. Is that a yes or a no?

Mr. ROUSH. Yes.

Mr. KUCINICH. Well, let me ask you then, because I need your help on this, Mr. Roush, one Georgia cotton farmer likened the Roundup resistant weeds choking cotton fields in Georgia to the boll weevil, which of course was a lethal threat to cotton farming there. In your opinion, as an Indiana corn and soy farmer, how serious a threat is herbicide-resistant weeds to farmers, and how serious an environmental threat is the potential solution of using more and more toxic herbicides?

Mr. ROUSH. Well, the threat is very serious. But quite frankly, the solution is worse than the threat. Specifically Dicamba. I have seen Dicamba do terrible things to fruit and vegetable crops. In one instance, I saw a tomato field, and it was a fan pattern, and the crop was destroyed. And it was obviously Dicamba damage. No one could figure it out. We walked up toward a barn, and in this barn was an open jug of Dicamba. The lid was off of it, a 2½ gallon jug. It had volatized out of the jug and went into the—that is how dangerous this chemical is. It has to be looked at.

Mr. KUCINICH. Let me ask you this as a followup. If you have glyphosate-resistant, or rather, glyphosate-tolerant crops, inadvertently ushered in glyphosate-tolerant weeds, isn't it likely in the world as we know it today that the commercialization of multiple herbicide-resistant crops will similarly facilitate multiple herbicide-resistance in weeds?

Mr. ROUSH. That would be likely, yes.

Mr. KUCINICH. And Mr. Kimbrell, what responsibility does the U.S. Department of Agriculture have for the proliferation of the superweeds problem?

Mr. KIMBRELL. They bear an enormous responsibility. Under the Plant Protection Act, they have the authority and they have had the authority since, remember, they approved, that is deregulated all the crops we are talking about. And they did all of it without a single Environmental Impact Statement, despite their commitment that they would do a programmatic Environmental Impact Statement, which would cover all these issues we are talking about.

Mr. KUCINICH. Was there any change in the policy under the new Secretary?

Mr. KIMBRELL. I wish I could give you an optimistic answer, Mr. Chairman, on that.

Mr. KUCINICH. Well, wait. Is there anything the Obama administration could do differently to prevent the proliferation of superweeds and the use of more toxic herbicides in farm fields?

Mr. KIMBRELL. Oh, my goodness. Well, first of all, how about doing an actual Environmental Impact Statement that actually looks at this issue? Again, we are looking at this issue de novo here, at this subcommittee level. This is the information that should have gone into the USDA in the 1990's, late 1990's and the last 10 years, and they should have been making it available to both policymakers and the farmers. They have not done that. They have not done that to this day.

As a matter of fact, up to this point, USDA says under the Plant Protection Act they are either not sure or they are pretty sure they will not have to do that in their Environmental Impact Statements. And now courts have ordered on alfalfa and sugar beets. They admit they now have to look at gene flow. But they are still not admitting that they need to look at this serious issue in an environmental statement, hoping that they will come out with an EIS sooner or later.

Mr. KUCINICH. I thank all the gentlemen for their cooperation in answering the questions. I now recognize Mr. Jordan for 10 minutes.

Mr. JORDAN. Thank you, Mr. Chairman. I appreciate our witnesses. I did notice that we have two Ohio ones and two Members from Illinois, we have a Purdue and Iowa State and a Penn State guy here. Fine people, but I am sure we could also add a Buckeye, maybe one from the Fighting—got a Buckeye background?

Mr. WELLER. I have a masters from Ohio State.

Mr. JORDAN. God bless you, I knew we had to have one in the crowd. [Laughter.]

Thank you all for joining us.

Let me go to Mr. Owen and Professor Weller and kind of cut to the chase. How many of the superweeds came through the gene flow, I think was the term I heard, I am certainly no expert in this area, but through the gene flow of genetically engineered crops? To me that seems to be the crux of the matter.

Mr. OWEN. None.

Mr. JORDAN. Am I wrong?

Mr. OWEN. None. There are no sexually compatible weeds with corn, soybean and cotton in the areas that they are produced. Thus none of the herbicide resistant, I really do not care for, from an ecological perspective, the term "superweeds." So herbicide-resistant weeds, there is no evidence and no possibility that gene flow could accommodate the evolution of glyphosate-resistant weeds in cotton, corn and soybean.

Mr. JORDAN. OK. Let me ask you this. Is this the first time farmers have had to deal with herbicide-resistant weeds?

Mr. OWEN. Absolutely not. We have had major problems with herbicide resistance for a number of years. Notably for example, all of the common waterhemp in Iowa, which is a lot, is functionally resistant to all ALS inhibitor herbicides. So this is not a new problem that we have been dealing with as weed scientists.

Mr. JORDAN. I want to be clear, and we will get all of the professors. I want to be clear. So farmers were experiencing problems with herbicide-resistant weeds before we had genetically engineered crops?

Mr. OWEN. Absolutely.

Mr. JORDAN. Care to elaborate, Mr. Weller? I thought you had something to add.

Mr. WELLER. Do you want me to add?

Mr. JORDAN. No, I think it is pretty plain. So talk to me about the approval process.

Mr. MORTENSEN. Can I add something?

Mr. JORDAN. Sure.

Mr. MORTENSEN. I think in my view, the point that you raise is a good one, resistance has been around for a long time. I am trying to remember back exactly, but atrazine was an herbicide that was used widely in corn. There were a number of species that evolved resistance to atrazine.

What in my view is very unique about the problem that we are addressing today is that we have a crop that was bred to be resistant to an herbicide that it had previously been susceptible to. And that we now see, and people pay a premium to use that seed. And the seed and the herbicide go together as a package. That has not happened before. And we see 92 percent of the soybean acreage is of this kind of soybean, and I don't have exact statistics, but 65 percent of the corn and 70 percent of the cotton.

So this is unlike anything we have encountered before in that regard. The scope and the consistent use of something that you are paying the premium for.

Mr. JORDAN. How recent, and I will let you speak, I know you want to jump in, Professor, how recent has this whole Roundup Ready, how recent is this phenomena? Refresh my memory, because I talked with our farmers.

Mr. WELLER. Roundup resistant soybeans were released in 1996. And corn, no, cotton was 1997, and then corn, 1998. So about 14 years, these crops have been on the market.

Mr. JORDAN. And if you don't go that approach, what would the farmer have to do different? If he is not going to go the Roundup Ready approach, are you talking, back when I was a kid, get the tractor out, cultivate, run the tractor more often, till the ground more often? Is it that alternative? Assuming they are going to rotate crops, which good farmers are going to do, is that the choice that they face? Is it that basic?

Mr. WELLER. One thing I would like to add to what Dr. Mortensen said——

Mr. JORDAN. Add to it, but then answer my question.

Mr. WELLER. Yes. Then I will answer your question. It is not totally true, it is true in the sense that there has never been a genetically engineered crop prior to Roundup that allowed you to use an herbicide in it. But in the case of corn, corn is naturally tolerant to atrazine. So in fact, we had a crop on the market, I mean an herbicide on the market that the crop was in essence resistant to a long time before 1996. Because atrazine has been on the market since about 1956, I believe.

Mr. JORDAN. It was naturally resistant?

Mr. WELLER. It was naturally resistant. The natural resistance is based on corn metabolizing the herbicide into an inactive form. The weeds can't do that.

Mr. JORDAN. OK.

Mr. WELLER. So we did have some experience. And when we got the atrazine resistance, to me, we have many of the same issues with all of the different types of herbicide resistances that we have dealt with in general. We developed a whole toolbox of weed management techniques from before we had herbicides until after we had herbicides. This includes some form of tillage, or even before tractors, hand hoeing, crop rotation, so you crop, and Dave is much more of an expert on this than I am, but certain weeds are more likely to be a problem in some crops than others. So you might rotate to a more competitive crop to get rid of those.

So integrated weed management is the approach to deal with all weed problems. In the case of herbicide resistance, and it goes back to Chairman Kucinich's comment, yes, the approach from a chemical standpoint is tank mixes of herbicides. In the case of atrazine-resistant cory, we always used these chlorosetamide type of herbicides, trade names were Lasso, Dual. And they are all soil-applied.

And those got rid of most of the weeds that were not being controlled by atrazine.

So in the case of glyphosate, we have seen an increase in preemergence herbicides applied. You can say all herbicides are toxic if you want to put it that way. But most of the herbicides that have come on the market since the 1980's generally are relatively non, lower toxicity than some of the older compounds. 2,4-D and Dicamba would be two of the older compounds.

So tank mixtures, crop rotations, addressing weeds with different management techniques is the way we have always dealt with weeds, whether they are resistant or not, so that they don't buildup and become a problem. The novelty of this is, we had this herbicide, as you asked me, it was infallible, well, it wasn't infallible. People thought it was. They applied only that. We had Roundup Ready crops, corn, soybeans. Those were rotated. They used Roundup. Bad management.

Wasn't the crop's fault. It was the management's fault, my feeling.

Mr. JORDAN. So it is not as basic as I described, where they are going to have to choose one option or the other. It is a comprehensive integrated approach is the best way to handle this all?

Mr. WELLER. Yes.

Mr. JORDAN. You are not advocating we—I mean, farmers are going to use herbicide. If they have to go to something else, there is a cost associated with that, frankly, maybe less yields, etc., that may be associated with that. So it is a comprehensive integrated approach.

Mr. WELLER. Well, and the one negative in the glyphosate case, glyphosate-resistant crops allowed us to go to massive acreages of no-till. So we met a lot of the rules and regulations about tillage. We may have to, as Dave mentioned earlier, some types of minimal tillage could play a role in that again. We have to consider what the economic and the environmental aspect of those practices are.

Mr. JORDAN. Do our professors and our farmer, do you share the same criticism of the agency that Mr. Kimbrell does? And maybe give the committee a little insight into the approval process both the EPA has for the herbicide and USDA has for the engineered crops? Elaborate on that if you will.

Mr. ROUSH. I am certainly no expert on any of that. I deal with the ramifications of what comes down the pike, of course. And I see the ramifications of what is coming down the pike, and that is my concern.

Mr. JORDAN. Professor.

Mr. OWEN. I am very much unfamiliar with the specifics that are referenced. But I have followed this a little bit. When we are working with regulated materials, we follow whatever requirements are placed upon us. But as far as how the agency behaves otherwise, I honestly don't know.

Mr. JORDAN. Let me do one thing. Mr. Mortensen has advocated a tax on herbicides, I believe, in one of his four or five suggestions. Do the rest of you share that? I mean, I would point out that the one sector of our overall economy that is doing relatively well is agriculture. Profits were up, we had a figure, net farm income is forecast to be $63 billion this year $6.7 billion or 11 percent, almost

12 percent increase from last year. So that is one sector of our economy that is looking pretty good.

Would you advocate taxing herbicides and putting that additional cost on agriculture?

Mr. OWEN. Absolutely not.

Mr. JORDAN. Mr. Weller.

Mr. WELLER. I agree, no.

Mr. JORDAN. And let's talk to the farmer.

Mr. ROUSH. Sure, as long as the funds were properly allocated to public research.

Mr. JORDAN. Mr. Kimbrell.

Mr. KIMBRELL. Yes, I just want to, whatever the issue, yes or no on tax, I think it would be a shame if that cloud over the central point of Professor Mortensen's, which is that we need Federal funding for independent, university research, independent university research, to track the emergence of these weeds. We do not have that database. That is the database we all were looking for. It seems to me that the tax, maybe there has to be some funding mechanism. I am not sure tax is it.

But let's not forget that this is a really important area, where university researchers could be invaluable in helping us track the emergence of this growing crisis.

Mr. MORTENSEN. And understand if you will the program that I chaired last year, I spent my own time down in D.C. chairing the national research program in weed and invasive organisms. It was eliminated 4 months ago. The 406 funds that fund weed science and integrated pest management research were eliminated about a month ago.

There is no public sector funding, or very limited. There is a critical issues program that was recently established. But it is not going near far enough to address the kinds of things we have been discussing today. And I am confident and certain that it will not be done by the companies.

Mr. OWEN. And I would be, if I may, unless we take with the research the opportunity to extend that information to the growers, because research without information and transmittal of information is of no value. So extension is also a very important component.

Mr. KUCINICH. I thank the gentleman. We are going to, Ms. Kaptur has kindly yielded to Mr. Foster. You are recognized.

Mr. FOSTER. Thank you so much. I apologize, I may have to jump out for votes in a different committee.

My first question, is it unambiguous, is the biochemical mechanism for the glyphosate resistance in the superweeds identical or different from the mechanism in the GM traits? And is there any ambiguity about whether or not this thing could have been, the gene could have jumped? Or is it absolutely clear to everyone that the gene did not jump, it was independently evolved?

Mr. WELLER. There are, I believe, three cases of weeds that have developed a certain level of resistance to glyphosate due to an alteration in the amino acid sequence on the enzyme that glyphosate inhibits. Two of those weeds are in Australia. They are rigid ryegrass and Lolium. And the third weed is goosegrass, which is in

Malaysia. So to my knowledge, none of the weeds in the United States have this alteration at the site of the action.

In the case of the weeds in the United States, much of it is unknown, the specific mechanisms. But in the case of, at least the palmer amaranth that was examined in Georgia, and that doesn't mean they are all this way, but people assume it is, it has more of the enzyme that glyphosate inhibits. So it has like 150 times as many copies of the EPSP synthase enzyme. You can't put enough glyphosate on it to kill it.

In the case of several others, it has been shown that the glyphosate, there is limited translocation to growing points. And that is where the plant is injured, but it starts re-growing.

Mr. FOSTER. My apologies. I do have to disappear for a vote. I will give you a couple of questions for the record.

Mr. WELLER. Sure.

Mr. KUCINICH. I thank the gentleman.

Mr. Schock, you are recognized for 5 minutes.

Mr. SCHOCK. Thank you. I have been very interested by all of your comments. As I mentioned in my opening statement, there doesn't seem to be a whole lot of disagreement on the panel about what is happening. We have weeds throughout our history of farming that become immune to the herbicides that are used against them. And in the case of farmers who do not provide, who do not participate in crop rotation and rotation of their herbicides and pesticides that are used, the problem is exacerbated. Does anybody disagree with that?

Mr. MORTENSEN. I think, at least I seem to be the outlier here of the three weed scientists on this point. One of the, to me, a really important distinction is that we have an herbicide that we basically can use in just, well, certainly in Midwest, year after year now, because we have, unlike the case where you could use atrazine in corn and you had resistance, and weeds in corn, you go to soybeans and you don't use atrazine, and you are not selecting for the weed population year in and year out.

The thing that is unique about this is that we are using this compound a lot. And there are more registrations that are in review right now for other crops to be added where the same active ingredient that can be used——

Mr. SCHOCK. Let me interrupt then. And I agree.

My question would be this, then. Would you agree that if it is being done year after year after year with the same crop, year after year after year, that would be contradictory to the EPA label found on the product and best practices for crop rotation and weed management?

Mr. MORTENSEN. I would agree that would not be a good thing.

Mr. OWEN. Truthfully, any practice that is repeated recurrently, whether it be tillage or no tillage, or herbicide, and we have history where we used the same mechanism of action on both crops, corn and soybean, in the 1980's, with the ALS inhibitors. But anything that you do recurrently is going to cause a shift in the weed population to allow something that doesn't respond to whatever it is that you are doing to become the dominant feature of a particular crop field.

Mr. SCHOCK. Professor Mortensen, first let me say this. I think what I was trying, and the point that I made in my opening statement was that it makes sense for farmers to do what is right. Obviously to invoke best practices, to follow the EPA prescribed guidelines on the chemicals that are being used, vis-a-vis the crops that are being planted. And really, by and large, this problem can be mitigated through proper farming techniques.

Now, as I mentioned, we have bad actors. We have people who don't follow it. And as a result, 0.08 percent of our world's farm ground is being affected by so-called superweeds, or herbicide-resistant weeds. Now, I am not suggesting that 0.08 percent of farm ground is insignificant. But what I am suggesting is that some of the prescriptions for the cure I would argue are worse than the disease itself.

I want to focus on your recommendations, Mr. Mortensen. Specifically, I have read your five recommendations. And No. 3 suggests that the Government should ensure farm level herbicide management planning.

How does the Government ensure farm level herbicide management planning?

Mr. MORTENSEN. There would be actually several ways that it could be done. Right now, the B.t. is regulated at the farm level, which is for insect resistance management. We could easily imagine a case where the amount of glyphosate, for example, that is sold for a certain number of acres that a farmer is farming would be something that you would keep track of and not have somebody have enough of the glyphosate that it is going to be used on the entire farm.

You could require, as is the case with CAFO requirements for water quality, insurance, as in my own State, where there are dairy farms, where you are concerned about water quality issues. We have rules where farmers have to have a water quality soil management plan in place. I don't see any reason why we couldn't have a pest management plan in place at the farm level.

Mr. SCHOCK. The chairman has very politely informed me that my time is expired.

Mr. KUCINICH. We are going to have another round.

Mr. SCHOCK. All I would say, now that my time is expired, is I think that it would be far more effective for us to promote education as the form of encouragement to farmers to prohibit this as opposed to additional regulation and Government involvement. I yield back.

Mr. KUCINICH. I thank the gentleman. We are going to have another round and you will be welcome to participate in it.

The Chair recognizes Ms. Kaptur.

Mr. KAPTUR. Thank you, Mr. Chairman, very much, for holding this extremely important hearing. I wish to place in the record, with unanimous consent, an article, if it has not been placed in the record by other Members, that was in the New York Times on May 4th, entitled "The Rise of the Superweeds."

Mr. KUCINICH. Without objection.

[The information referred to follows:]

May 3, 2010

Farmers Cope With Roundup-Resistant Weeds

By **WILLIAM NEUMAN** and **ANDREW POLLACK**

DYERSBURG, Tenn. — For 15 years, Eddie Anderson, a farmer, has been a strict adherent of no-till agriculture, an environmentally friendly technique that all but eliminates plowing to curb erosion and harmful runoff of fertilizers and pesticides.

But not this year.

On a recent afternoon here, Mr. Anderson watched as tractors crisscrossed a rolling field — plowing and mixing herbicides into the soil to kill weeds where soybeans will soon be planted.

Just as the heavy use of antibiotics contributed to the rise of drug-resistant supergerms, American farmers' near-ubiquitous use of the weedkiller Roundup has led to the rapid growth of tenacious new superweeds.

To fight them, Mr. Anderson and farmers throughout the East, Midwest and South are being forced to spray fields with more toxic herbicides, pull weeds by hand and return to more labor-intensive methods like regular plowing.

"We're back to where we were 20 years ago," said Mr. Anderson, who will plow about one-third of his

3,000 acres of soybean fields this spring, more than he has in years. "We're trying to find out what -ks."

Farm experts say that such efforts could lead to higher food prices, lower crop yields, rising farm costs and more pollution of land and water.

"It is the single largest threat to production agriculture that we have ever seen," said Andrew Wargo III, the president of the Arkansas Association of Conservation Districts.

The first resistant species to pose a serious threat to agriculture was spotted in a Delaware soybean field in 2000. Since then, the problem has spread, with 10 resistant species in at least 22 states infesting millions of acres, predominantly soybeans, cotton and corn.

The superweeds could temper American agriculture's enthusiasm for some genetically modified crops. Soybeans, corn and cotton that are engineered to survive spraying with Roundup have become dard in American fields. However, if Roundup doesn't kill the weeds, farmers have little incentive to spend the extra money for the special seeds.

Roundup — originally made by Monsanto but now also sold by others under the generic name glyphosate — has been little short of a miracle chemical for farmers. It kills a broad spectrum of weeds, is easy and safe to work with, and breaks down quickly, reducing its environmental impact.

Sales took off in the late 1990s, after Monsanto created its brand of Roundup Ready crops that were genetically modified to tolerate the chemical, allowing farmers to spray their fields to kill the weeds while leaving the crop unharmed. Today, Roundup Ready crops account for about 90 percent of the soybeans and 70 percent of the corn and cotton grown in the United States.

But farmers sprayed so much Roundup that weeds quickly evolved to survive it. "What we're talking about here is Darwinian evolution in fast-forward," Mike Owen, a weed scientist at Iowa State University, said.

Now, Roundup-resistant weeds like horseweed and giant ragweed are forcing farmers to go back to · ~e expensive techniques that they had long ago abandoned.

Mr. Anderson, the farmer, is wrestling with a particularly tenacious species of glyphosate-resistant pest called Palmer amaranth, or pigweed, whose resistant form began seriously infesting farms in western Tennessee only last year.

Pigweed can grow three inches a day and reach seven feet or more, choking out crops; it is so sturdy that it can damage harvesting equipment. In an attempt to kill the pest before it becomes that big, Mr. Anderson and his neighbors are plowing their fields and mixing herbicides into the soil.

That threatens to reverse one of the agricultural advances bolstered by the Roundup revolution: minimum-till farming. By combining Roundup and Roundup Ready crops, farmers did not have to plow under the weeds to control them. That reduced erosion, the runoff of chemicals into waterways and the use of fuel for tractors.

If frequent plowing becomes necessary again, "that is certainly a major concern for our environment," Ken Smith, a weed scientist at the University of Arkansas, said. In addition, some critics of genetically engineered crops say that the use of extra herbicides, including some old ones that are less environmentally tolerable than Roundup, belies the claims made by the biotechnology industry that its crops would be better for the environment.

"The biotech industry is taking us into a more pesticide-dependent agriculture when they've always promised, and we need to be going in, the opposite direction," said Bill Freese, a science policy analyst for the Center for Food Safety in Washington.

So far, weed scientists estimate that the total amount of United States farmland afflicted by Roundup-resistant weeds is relatively small — seven million to 10 million acres, according to Ian Heap, director ie International Survey of Herbicide Resistant Weeds, which is financed by the agricultural chemical industry. There are roughly 170 million acres planted with corn, soybeans and cotton, the crops most affected.

. .ndup-resistant weeds are also found in several other countries, including Australia, China and Brazil, according to the survey.

Monsanto, which once argued that resistance would not become a major problem, now cautions against exaggerating its impact. "It's a serious issue, but it's manageable," said Rick Cole, who manages weed resistance issues in the United States for the company.

Of course, Monsanto stands to lose a lot of business if farmers use less Roundup and Roundup Ready seeds.

"You're having to add another product with the Roundup to kill your weeds," said Steve Doster, a corn and soybean farmer in Barnum, Iowa. "So then why are we buying the Roundup Ready product?"

Monsanto argues that Roundup still controls hundreds of weeds. But the company is concerned enough about the problem that it is taking the extraordinary step of subsidizing cotton farmers' purchases of competing herbicides to supplement Roundup.

Monsanto and other agricultural biotech companies are also developing genetically engineered crops resistant to other herbicides.

Bayer is already selling cotton and soybeans resistant to glufosinate, another weedkiller. Monsanto's newest corn is tolerant of both glyphosate and glufosinate, and the company is developing crops resistant to dicamba, an older pesticide. Syngenta is developing soybeans tolerant of its Callisto product. And Dow Chemical is developing corn and soybeans resistant to 2,4-D, a component of Agent Orange, the defoliant used in the Vietnam War.

Still, scientists and farmers say that glyphosate is a once-in-a-century discovery, and steps need to be t n to preserve its effectiveness.

Glyphosate "is as important for reliable global food production as penicillin is for battling disease," Stephen B. Powles, an Australian weed expert, wrote in a commentary in January in The Proceedings ıe National Academy of Sciences.

The National Research Council, which advises the federal government on scientific matters, sounded its own warning last month, saying that the emergence of resistant weeds jeopardized the substantial benefits that genetically engineered crops were providing to farmers and the environment.

Weed scientists are urging farmers to alternate glyphosate with other herbicides. But the price of glyphosate has been falling as competition increases from generic versions, encouraging farmers to keep relying on it.

Something needs to be done, said Louie Perry Jr., a cotton grower whose great-great-grandfather started his farm in Moultrie, Ga., in 1830.

Georgia has been one of the states hit hardest by Roundup-resistant pigweed, and Mr. Perry said the ɪ . could pose as big a threat to cotton farming in the South as the beetle that devastated the industry in the early 20th century.

"If we don't whip this thing, it's going to be like the boll weevil did to cotton," said Mr. Perry, who is also chairman of the Georgia Cotton Commission. "It will take it away."

William Neuman reported from Dyersburg, Tenn., and Andrew Pollack from Los Angeles.

Ms. KAPTUR. Thank you. I will just read one statement from Andrew Wargo, III, President of the Arkansas Association of Conservation Districts, that the impact of these genetically resistant weeds is the "single largest threat to production agriculture that we have ever seen." That is interesting for someone from the State of Arkansas, but the article goes on and it mentions many of the concerns we have been talking about here today.

Let me just state for the record that I have legislation that I would also like to place on the record here, H.R. 3299, I have reintroduced in this Congress, called the Seed Saver Legislation, to allow farmers to save their seeds and to actually pay royalties to the Department of Agriculture at levels that they assess, not to the seed companies. And incredible concentration in the seed market has priced many of our farmers out of the market and given seed companies, not the seed dealers, unnatural control over who holds the power of life.

While this is not the primary purpose of this hearing, Mr. Chairman, I would like some of the panelists to comment here on the incredible concentration of the seed market and the market-manipulating actions of these companies. I wanted to ask Mr. Roush if in fact he has to pay technology fees when you purchase your seeds, and also, do you have the ability to harvest the seeds that you purchase?

[The information referred to follows:]

I

111TH CONGRESS
1ST SESSION

H. R. 3299

To require persons who seek to retain seed harvested from the planting of patented seeds to register with the Secretary of Agriculture and pay fees set by the Secretary for retaining such seed, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

JULY 22, 2009

Ms. KAPTUR introduced the following bill; which was referred to the Committee on Agriculture, and in addition to the Committee on Ways and Means, for a period to be subsequently determined by the Speaker, in each case for consideration of such provisions as fall within the jurisdiction of the committee concerned

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A BILL

To require persons who seek to retain seed harvested from the planting of patented seeds to register with the Secretary of Agriculture and pay fees set by the Secretary for retaining such seed, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Seed Availability and Competition Act of 2009".

SEC. 2. RETAINING PATENTED SEED.

(a) REGISTRATION.—Any person who plants patented seed or seed derived from patented seed may retain seed from the harvest of the planted seed for replanting by that person if that person—

(1) submits to the Secretary of Agriculture notice, in such form as the Secretary may require, of the type and quantity of seed to be retained and any other information the Secretary determines to be appropriate; and

(2) pays the fee established by the Secretary pursuant to subsection (b) for the type and quantity of seed retained.

(b) FEES.—The Secretary of Agriculture shall establish a fee to be paid by a person pursuant to subsection (a)(2) based on the type and quantity of seed retained. The Secretary shall deposit amounts collected pursuant to subsection (a)(2) in the Patented Seed Fund established under subsection (e)(1).

(c) REFUNDS.—The Secretary of Agriculture may refund or make an adjustment of the fee paid pursuant to subsection (a)(2) when the person is unable to plant or harvest the retained seed as a result of a natural disaster or related condition and under such other circumstances as the Secretary considers such refund or adjustment appropriate.

(d) DISTRIBUTIONS.—The Secretary of Agriculture shall pay the collected fees to the appropriate patent holders, at a frequency that the Secretary determines is appropriate, from the Patented Seed Fund established under subsection (e)(1), taking into consideration the possibility of refunds pursuant to subsection (c).

(e) PATENTED SEED FUND.—

(1) ESTABLISHMENT.—There is established in the Treasury of the United States a fund to be known as the "Patented Seed Fund", consisting of such amounts as may be received by the Secretary and deposited into such Fund as provided in this section.

(2) ADMINISTRATION.—The Fund shall be administered by the Secretary of Agriculture and all moneys in the Fund shall be distributed solely by the Secretary in accordance with this section and shall not be distributed or appropriated for any other purpose. Amounts in the Fund are available without further appropriation and until expended to make payments to patent holders.

(f) INAPPLICABILITY OF CONTRACTS AND PATENT FEES.—A person who retains seed under subsection (a) from the harvest of patented seed or seed derived from patented seed shall not be bound by any contractual limitation on retaining such seed, or by any requirement to pay royalties or licensing or other fees, by reason of the patent, for retaining such seed.

(g) DEFINITION.—In this section, the term "patented seed" means seed for which a person holds a valid patent.

SEC. 3. TARIFF ON CERTAIN IMPORTED PRODUCTS.

(a) TARIFF.—In any case in which—

(1) genetically modified seed on which royalties or licensing or other fees are charged by the owner of a patent on such seed to persons purchasing the seed in the United States is exported, and

(2) no such fees, or a lesser amount of such fees, are charged to purchasers of the exported seed in a foreign country,

then there shall be imposed on any product of the exported seed from that foreign country that enters the customs territory of the United States a duty determined by the Secretary of the Treasury, in addition to any duty that otherwise applies, in an amount that recovers the difference between the fees paid by purchasers of the seed in the United States and purchasers of the exported seed in that country.

(b) DEPOSIT OF DUTIES.—There shall be deposited in the Patented Seed Fund established under section 2(e)(1) the amount of all duties collected under subsection

(a) for distribution to the appropriate patent holders in accordance with section 2(d).

(c) DEFINITIONS.—In this section—

(1) the term "genetically modified seed" means any seed that contains a genetically modified material, was produced with a genetically modified material, or is descended from a seed that contained a genetically modified material or was produced with a genetically modified material; and

(2) the term "genetically modified material" means material that has been altered at the molecular or cellular level by means that are not possible under natural conditions or processes (including recombinant DNA and RNA techniques, cell fusion, microencapsulation, macroencapsulation, gene deletion and doubling, introducing a foreign gene, and changing the positions of genes), other than a means consisting exclusively of breeding, conjugation, fermentation, hybridization, in vitro fertilization, tissue culture, or mutagenesis.

Mr. ROUSH. I think you mean do I have the ability to retain or keep the seeds?

Ms. KAPTUR. Yes.

Mr. ROUSH. No, I do not.

Ms. KAPTUR. I don't think most Members of Congress really understand this.

Mr. ROUSH. I don't think they understand the issue at all. The Supreme Court has usurped the law of the land, which is the Plant Variety Protection Act. And I will leave it at that.

Ms. KAPTUR. I wanted to mention, in terms of Mr. Kimbrell's testimony, that APHIS funding levels in the recent 2011 budget provided an additional $6 million to assess the risks of genetically modified organisms for the Biotechnology Regulatory Service. The budget provides about $19 million for the overall services there within APHIS, to assess the risks of forthcoming genetically modified organisms. This is an increase compared to the prior year.

I am wondering if you are stating that is not sufficient. I just want to understand what you are saying about the budgetary levels of USDA.

Mr. KIMBRELL. Yes, and if I may, I cannot resist commenting on the first thing you brought up. It is true right now that Monsanto owns 25 percent of the world's commercial seeds, together with Syngenta, Bayer, Dow and Dupont, they own almost 50 percent of all the world's commercial seeds. We have seen a massive and significant rise in the cost of corn.

Mr. KAPTUR. If the gentleman would yield, I don't think the American people really understand that the seeds of life are now controlled by chemical companies for the most part.

Mr. KIMBRELL. Yes, and I think that the manner in which they control them is through acquisition of seed companies, through patenting of those seeds, through genetic engineering of those seeds, and through potentially something called terminator technology, which would be a technology which has the seeds basically infertile after one growing season. So we are facing a hidden crisis in seed diversity, we are letting a few chemical companies decide which seeds on the earth are going to be available to farmers, which are not.

If this were water or oil, we would realize the crisis we are in. I just want to undergird what you are saying, I think it is terribly important.

Mr. KAPTUR. If you have recommendations, or Mr. Roush, on what we might do about that through your organizations, I hope you will get back to us on that.

Mr. KIMBRELL. Yes. Thank you. And as far as, to me the problem, and I really should, I can get back to the subcommittee on this, to me the problem with appropriations is not as important as the problem of exactly who the agency seems to be serving. And having witnessed these five litigations, all lost by APHIS, having looked at the IG and the GAO report and the Farm Bill, it seems to me that the USDA, now with this administration as well, but certainly in the last administration, is bending over backward to find excuses not to do an Environmental Impact Statement, excuses not to look at the economic harm. And to this day refusing even to look at the issue which is the central issue of this hearing.

So regardless, if they have the money and they are not spending it actually doing the work they have to do, it seems to me that is the problem. Whether that is actually adequate to do that job, somebody else would have to say. But again, I want to re-emphasize and say here, I certainly do not like to see the agency relying solely on the information being given by the companies. I would certainly think that one way to spend that money would be to get independent, university researchers like some of the people on this panel to really look at the emergence of these superweeds and give us the kind of information we need, and then put that in the Environmental Impact Statement.

Ms. KAPTUR. I read you loud and clear on that.

I know my time is expired, Mr. Chairman, but I do want to ask Mr. Roush, what fee on Roundup Ready soybeans do you have to pay per year?

Mr. ROUSH. That is unclear . It is buried in the price of the seed. It quite frankly depends on whether or not it is generation 1 or generation 2 Roundup Ready. It is very unclear.

Mr. KUCINICH. I am going to have to interrupt. There is a vote in progress. We are going to have to go.

I thank the gentlelady, the gentlelady's time is expired. I am going to recess this hearing until about a quarter after 4, and we will come back for the next round of questions.

[Recess.]

Mr. KUCINICH. The committee will come to order.

I want to thank the members of the panel for their presence, and for their patience. We had four votes, and now I am going to do the best I can to get through a few other questions. We have about another 15 minutes worth of questions, and I am going to begin.

Professors Owen and Weller, in your written testimony, both of you identify farm mis-management as the main culprit in causing herbicide resistance in weeds. Staff, will you distribute an exhibit to the witnesses?

While it is being distributed, I am going to read the text in case you can't see it. It says, researchers also found no benefit in rotating glyphosate with other herbicides. "The important finding is that telling growers to use glyphosate 1 year and not the next year has no advantage over using glyphosate every year at recommended rates." Dr. Wilson said, "The concept of rotating glyphosate with alternative chemistries hasn't proven any more effective than just properly applying glyphosate." Following 7 years of research, Dr. Wilson says the basic message remains unchanged: don't cut the recommended rate of Roundup.

So here is Monsanto telling farmers to use more and more Roundup and to use it exclusively to control weeds. That was only 5 years ago. Isn't it true that if farmers followed the advice Monsanto was giving, they would have Roundup-resistant weeds in their fields today?

Mr. OWEN. Yes.

Mr. KUCINICH. Anyone else?

Mr. MORTENSEN. Yes.

Mr. ROUSH. I received that advice, and yes.

Mr. KUCINICH. Professor Mortensen, Monsanto made a lot of money with farmers following that advice. Isn't it true that

Monsanto's Roundup Ready seeds and Roundup herbicide virtually took over the market and that is what exerted natural selection pressure on weeds to select for resistance to Roundup?

Mr. MORTENSEN. Yes, it is.

Mr. KUCINICH. Professors Owen and Weller, to resolve the problem of herbicide resistance in weeds going forward, you both put your faith in public education to inform farmer decisions. That sounds a lot like the plan that got us into the problem we currently have. At what point would your policy recommendations expand from a sole reliance on public education efforts? In your view, is there ever a role for Federal regulation? Professor Owen?

Mr. OWEN. I think there has to be a role for regulation at some point. In trying to envision this and anticipating the question before I arrived here, I was basically at loggerheads trying to figure out how that could be actually implemented. Because I see what has been relatively effective in my opinion with regard to IRM, insect resistance management.

But the biology of the insects and the biology of the weeds are so much different that I am having trouble seeing how that type of regulatory action would have any impact.

Mr. KUCINICH. Professor Weller.

Mr. WELLER. I agree with Dr. Owen, when he says the difference between insects and weeds. From my perspective, from a regulatory role, I would like to see what people would come up with as far as the basis for that. The comment on education is, to provide the grower with scientific-backed facts about what are the best ways to manage weeds. We know what happened when farmers followed the recommendations from Monsanto, Roundup, Roundup, Roundup. It is not good. We knew that. And I think from our point of view, we did counter that from the university point of view.

But I think the other comment that many farmers believed it, and it did make their weed control quite efficient for several years, until the selection pressure resulted in weeds that weren't as well controlled.

Mr. KUCINICH. Well, here is the point that I am making. How far along do you keep saying, well, use public education, what happens if you reach the point of infestation that is predicted by Syngenta scientists, 38 million acres of row crops? Do we still talk public education?

Mr. WELLER. From my perspective, that Syngenta comment is based on using only Roundup, not using an integrated weed management approach.

Mr. KUCINICH. OK. Good point.

Mr. WELLER. That would result in exactly the catastrophe that we have been talking about today.

Mr. KUCINICH. So what would be the tipping point to consider other policies, even a Federal role? And of mitigating the spread of herbicide-resistant weeds?

Mr. WELLER. I think one thing we have learned in the last 5 years, and Mike and I have been involved in a six-State study looking at weed management in Roundup Ready crops and other rotations, we have seen a change in farmers' approaches to management based on a lot of the best management practices that have been coming out from the universities.

Whether you can force farmers to do that without regulation, I don't know.

Mr. KUCINICH. Professor Owen, did you want to jump in on that one?

Mr. OWEN. Yes, I did. Dr. Weller makes a good point: can you force farmers to change? I don't think so. Even if you could, I don't know how you would enforce it. Your point about how far do we wait, well, we should have been doing this all along. A number of us made those recommendations and continue to make those recommendations. For example, in Iowa, we have approximately 1.25 FTEs dedicated to extension and weed science.

Mr. KUCINICH. Let me ask Professor Mortensen to jump in here. At what point, Professor, do you think it is time for the USDA and the EPA to step in with regulations aimed at preventing the spread of herbicide resistance in weeds?

Mr. MORTENSEN. I am of the opinion that this is, I think we are at that point. So I am of the opinion, being invited to come down here, I spent the better part of the past week reading and just sort of polishing up on some things to get ready to come down here. I actually am surprised at the extent, and I knew about the species count. I have been following that closely, from an ecology point of view that interested me a lot.

But I wasn't aware of the number of sites and the number of acres infested. I was actually honestly surprised at the high figures that I came up with that also corroborate figures that Ian Heap, the reported expert on this internationally, has been coming up with as well. I think we are at that point.

And the other thing that I echo the concern that Troy expressed about the solution from the companies' point of view is pretty far down the tracks. The gene insert train is on the tracks. I was at the University of Nebraska when we hired the director of the biotech center, who is Don Weeks, who is the person who received the patent at the University of Nebraska for the Dicamba gene. That was a contractual arrangement with Monsanto. And that was published in a 2007 science paper announcing this discovery.

We are 3 to 4 years away from seeing these crops planted in the field. Glyphosate Dicamba, glyphosate 2,4-D, and there has been very little discussion, there has been very little science, there is not near enough communication between EPA and APHIS about this, in fact, very little. I was invited down to EPA to talk about work we are doing on this subject about 4 months ago. The talk we gave was piped out across to all the EPA labs across the country. And it is clear that there is not enough communication between EPA and APHIS on how this is all progressing.

Mr. KUCINICH. Let me ask you about the USDA. Is it in the long-term interest of farmers for the USDA to continue approving new glyphosate-resistant crops, like Roundup Ready alfalfa and sugar beets, in the complete absence of effective resistant management plans?

Mr. MORTENSEN. No.

Mr. KUCINICH. And then Mr. Roush, I think that many people would want to believe that farmers are able to solve the problems of herbicide resistance in weeds on their own as a farmer. Do you agree with that?

Mr. ROUSH. No, absolutely not. We are working on advice from largely industry only The public sector, our public research is dead, it is decimated. So we are taking the advice of the people that are selling these compounds. And it is really frustrating. I got the impression early on that in a lot of ways, it feels like us farmers are being blamed for this issue. And yet we are working on advice from industry. It is exacerbating the problem.

Mr. KUCINICH. Let me turn the question a little bit. In your opinion, as a farmer, is it in the long-term interest of farmers to leave the Government off the hook for responsibility to prevent proliferation of superweeds?

Mr. ROUSH. I am kind of reluctant on that superweed, but resistant weed, I accept that term. No. It is not. Government has a role, if nothing else, in research and education. But even the potential solution is a bigger concern. I have stated repeatedly that I believe the solution to glyphosate-resistant weeds is worse than the problem. I would rather have the weeds than the Dicamba that they are proposing to solve the problem with.

Mr. KUCINICH. Just one final question here. Is there any lessons to be learned from, if any of you know this, Australia had some experience with herbicide resistance. And if any of you know about that and you would like to comment on that, what lessons could be learned? We have a video here.

[Video shown.]

Mr. KUCINICH. So are you familiar with Australia, Professor Owen?

Mr. OWEN. Yes, I am.

Mr. KUCINICH. And do you agree with Professor Powells that the Australian catastrophe of glyphosate-resistant weeds affecting half a continent is now unfolding here?

Mr. OWEN. I would not agree with him to the extent that we have the same system. They have a very unique agricultural system in western Australia and in the agricultural areas. There are lessons to be learned from the experience in Australia. But we have a much more diverse agriculture than they have. Thus, we have a lot more opportunities to manage this by incorporating different technologies that are currently available.

Mr. KUCINICH. Thank you.

Professor Mortensen, did you want to comment?

Mr. MORTENSEN. Yes. I think there are, I agree with Mike that the cropping systems in Australia are simpler. But one of the things that we explored in a recent paper that we published is that when you make the weed management that you are doing, which is the use of glyphosate, very similar year in and year out, actually in some ways we are not unlike that broad acre farming in Australia. Because what the problem in Australia is is that they are using much the same practices year after year. We are moving in that direction here.

Mr. KUCINICH. So you are saying down the road this could pose some implications that Australia is experiencing?

Mr. MORTENSEN. Yes.

Mr. KUCINICH. Are you familiar with Australia, Mr. Roush?

Mr. ROUSH. I have spent some time there, if you are asking. I have spent some time in Australia, yes.

Mr. KUCINICH. Are you familiar with their herbicide-resistance problem?

Mr. ROUSH. Yes, but here again, I am not a scientist, so I can't speak to it.

Mr. WELLER. Can I say something? I agree with Mike and David to a large degree. But I think the important point that Mike made was the cropping diversity allows us also to have a diverse array of herbicides that they don't have. There about 11 mechanisms of action of herbicide, most of which we can use in our corn, soybeans and cotton if they are registered. Whereas in Australia, they tend to be mostly in grain crops, more wheat, crops like that, which don't allow quite the diversity.

And the other thing, if I could talk for just one more minute, when you think about regulations, I think we have to think thoroughly what kind of program are we going to come up with. At this point, I think back to our education and the basis of research-generated knowledge, we need more funding to do those types of things, because I think right now the type of solution, if it is legislated or not, what we have is, what kind of cropping approaches with tank mixes of different herbicides are we going to come up with to require people to use.

I think we really want to get back more to a sustainable approach, are there non-chemical approaches, are there cover crops that can be used, are there alterations in tillage, and what are the herbicides that best fit into those systems to make it sustainable. I think that is what has to be thought through with regulations or not.

Mr. KUCINICH. I want to thank each of the witnesses. This has been a very important panel, the first one that Congress has held on this subject. This is something that has great implications for American agriculture and for people who make a living working the land.

So we honor the generations of working the land that your family has done, Mr. Roush, and just know that your presence here is very helpful. All the scientists who are here, and the years that you have spent in studying this, this subcommittee is very grateful for your presence. It helps us to look with a depth of knowledge into this issue.

We are going to continue to assert jurisdiction over this. There will be another hearing in September.

I am Dennis Kucinich, Chair of the Domestic Policy Subcommittee of Oversight and Government Reform. Today's hearing has been "Are 'Superweeds,'" as we call it, "an Outgrowth of the USDA Biotech Policy?" This is Part 1 of our inspection hearing. We have had a list of distinguished panelists and are very grateful for their presence here. This subcommittee stands adjourned. Thank you.

[Whereupon, at 4:40 p.m., the subcommittee was adjourned.]

[Additional information submitted for the hearing record follows:]

**Written Testimony for the Record of Adam Nielsen,
Director of National Legislation and Policy, Illinois Farm Bureau**

**Before a Hearing of the Committee on Oversight and Government Reform,
Subcommittee on Domestic Policy**

**<u>Are Superweeds an Outgrowth of USDA Biotech Policy?</u>
July 28, 2010**

The majority of Illinois farmers employ cropping systems that require the use of glysophate. Farmers adopted this valuable technology quickly because of the product's numerous agronomic attributes including better weed control, use of fewer pesticides, and the preservation of precious topsoil.

While Illinois Farm Bureau is concerned about the increased incidence of weed resistance in some parts of the state, there is no cause for alarm. Not only are we optimistic that the industry will find new solutions, we are also supportive of the current federal regulatory structure.

Finally, Illinois Farm Bureau is confident in our members' stewardship of all products that help us control weeds on our farms and allow us to produce food and fiber in the most cost effective and sustainable way possible.

Written Testimony for the Record of Illinois Corn Growers

Before a Hearing of the Committee on Oversight and Government Reform, Subcommittee on Domestic Policy

Are Superweeds an Outgrowth of USDA Biotech Policy?
July 28, 2010

Introduction
Weeds pose a constant problem for farmers. Most crops have innate resistance to some herbicides, but usually not those that control the specific weeds that affect them. This creates problems for the farmer. Biotechnology offers a solution that permits the use of newer, more effective, lower environmental impact herbicides in circumstances where it was not feasible before. Farmers can use safer controls and spray only as needed, which reduces the overall environmental impact. Superior weed control also increases productivity per acre.

Over time, it has become obvious that biotech crops provide significant environmental, economic, and social benefits, and that they are an integral tool in achieving sustainable agricultural production and feeding the hungry around the world. Decades of documented evidence demonstrate that agricultural biotechnology is a safe and beneficial technology. Farmers choose biotech crops because they produce more on less land while using environmentally friendly farming practices.

Background
Before the advent of herbicide-tolerant biotech crops, about 95 percent of U.S. farmland was treated with herbicides. Transgenic herbicide-tolerant crops have been grown in the USA since 1996 when glyphosate resistant (Roundup Ready) soybeans were introduced. By 2007, the percent of total acres planted of each crop that were genetically engineered: soybeans 91% ; canola 91%; corn 52%; cotton 70%. The acreages of non-genetically engineered HR crops are not readily available but a significant percentage of wheat in the Great Plains and the Pacific Northwest is imidazolinone-resistant wheat.

Resistant crops have been produced by crossing the crop with a resistant weed, mutagenesis, or molecular techniques. The movement of a resistant gene from a weed to a crop to produce a herbicide resistant crop was used to produce triazine resistant canola and imidazolinone resistant sunflower. Clearfield canola, rice, and wheat were produced through mutagenesis while the Roundup Ready and Liberty Link® crops are transgenic crops that are the result of genetic engineering.

Weed Resistance Occurs Regardless of Biotech Use
Changes in the troublesome weeds species identified over time illustrate the differences in the individual weed species responses to repeated selection with the predominant herbicides. In Georgia, sicklepod (*Senna obtusifolia*) and coffee senna (*Senna occidentalis*) were among the most troublesome weeds of cotton in surveys in 1974 (sicklepod only), 1983, and 1995. The natural tolerance of these two species to several of the commonly used cotton herbicides allowed them to persist and cause significant crop yield losses. With the introduction of glyphosate-resistant crops cultivars and the subsequent use of glyphosate for in-season weed control, neither sicklepod nor coffee senna was ranked among the most troublesome weeds in Georgia cotton in 2005 or 2009. Simply put, weed resistance is not an issue exclusive to biotechnology crops, but a common problem facing all farmers who use herbicides.

Weed Resistance is Not Exclusive to Glyphosate Use
Since herbicides are a principal means of weed control, there are reports of resistant weeds. A total of 347 confirmed occurrences of weed resistance have been compiled within 119 species. Within those 119, certain species are found more commonly than others. Weeds with resistance to herbicides are found on every continent, chiefly in developed countries where herbicides have been commonly used for several years. Resistance to 13 specific

herbicide modes of action and chemical classes have been reported. The highest and second highest numbers of resistant species are resistant to the ALS-inhibiting and triazine herbicides, respectively.

Conclusion

Farmers support the continued study of potential weed-resistance problems and further development of resistance-management best practices. No other group is more dependent upon the continued availability of effective herbicide technologies. Farmers are committed to best practices that will continue the efficacy of herbicides. Finally, herbicide-tolerant biotech crops allow farmers and their families to have less exposure to chemicals. This health benefit, while largely undocumented, should not be dismissed lightly.

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Congress of the United States

House of Representatives

COMMITTEE ON OVERSIGHT AND GOVERNMENT REFORM

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August 4, 2010

Mr. Stephen Weller, Ph.D.
Purdue University
Department of Horticulture and Landscape Architecture
625 Agriculture Mall Dr.
Office 315
West Lafayette, IN 47907

Dear Dr. Weller:

In connection with the July 28, 2010 hearing of the Domestic Policy Subcommittee hearing, entitled, "Are 'Superweeds' an Outgrowth of USDA Biotech Policy," I hereby request that you provide answers in writing to the following questions for the hearing record.

1. We received testimony that up to 11 million acres of American farmland are now infested with weeds exhibiting resistance to the herbicide glyphosate. We also heard testimony that such infestation occurred over a relatively short period of time, between 10 and 15 years.
   a. In your opinion, is it fair and accurate to characterize the proliferation of glyphosate resistant weeds in millions of acres of American farmland as a problem caused by a few bad actors – farmers who demonstrated reckless disregard for the rules and mores of farming?
   b. If not, what are the influences acting on farmer weed management decisions? For instance, what role, if any, do contractual obligations with genetically engineered seed companies and the price of genetically engineered seed play in the weed management decisions made by farmers?

2. We received testimony that a number of chemical manufacturers have petitioned USDA for deregulation of variants of soy, cotton and corn that have been genetically engineered to be tolerant of a number of existing herbicides. One of those petitions (10-188-01p) concerns a soybean designed to be tolerant of the herbicide Dicamba.
   a. Please elaborate on your experience with and knowledge of Dicamba, with particular respect to the impact on horticultural crops.

Dr. Stephen Weller
August 4, 2010
Page 2

b. Please share with the subcommittee your view as to the likely trend in Dicamba usage should a Dicamba-tolerant soybean be deregulated by USDA. In the context of that trend, please discuss the challenges to prevent unintentional damage to horticultural crops.
c. In your opinion, will public education adequately prevent the potential damage to horticultural crops that you foresee?
d. Does the existing biotech regulatory framework at USDA enable the agency to prevent the damage for horticultural crops you have already identified?

3. Herbicide resistance in weeds is not a new phenomenon, of course. However, in testimony and in the popular press, glyphosate resistance in weeds growing in cotton fields in Georgia and elsewhere has been likened to an industry threat. Can you provide any examples of past herbicide resistant weeds that threatened entire agricultural sectors?

The Oversight and Government Reform Committee is the principal oversight committee in the House of Representatives and has broad oversight jurisdiction as set forth in House Rule X. An attachment to this letter provides information on how to respond to the Subcommittee's request.

We request that you provide these answers in writing as soon as possible, but in no case later than **5:00 p.m. on Wednesday, August 25, 2010.**

If you have any questions regarding this request, please contact Jaron Bourke, Staff Director, at (202) 225-6427.

Sincerely,

Dennis J. Kucinich
Dennis J. Kucinich
Chairman
Domestic Policy Subcommittee

cc: Jim Jordan
Ranking Minority Member

PURDUE
UNIVERSITY

DEPARTMENT OF HORTICULTURE
AND LANDSCAPE ARCHITECTURE

August 24, 2010

Congressman Dennis J. Kucinich
Chairman, Domestic Policy Subcommittee
Congress of the United States
House of Representatives
2157 Rayburn House Office Building
Washington, DC 20515-6143

Dear Congressman Kucinich:

Below I have provided answers to the questions that you asked me as follow-up to my testimony before the Domestic Policy Subcommittee hearing on July 28, 2010 entitled, "Are 'Superweeds' an outgrowth of USDA Biotech Policy?". I have answered the questions posed to the best of my ability and ask if you need further clarifications to contact me at weller@purdue.edu and I would be pleased to provide additional information.

1. We received testimony that up to 11 million acres of American farmland are now infested with weeds exhibiting resistance to the herbicide glyphosate. We also heard testimony that such infestation occurred over a relatively short period of time, between 10 and 15 years.

    a. In your opinion, is it fair and accurate to characterize the proliferation of glyphosate resistant weeds in millions of acres of American farmland as a problem caused by a few bad actors - farmers who demonstrated reckless disregard for the rules and mores of farming?

       I do not feel it is appropriate to characterize the total problem of the proliferation of glyphosate resistant weeds on American farmland as the result of a few bad actors. As with all new and effective herbicides for weed management in cropland, the general tendency is to use these herbicides as much as possible because they are so effective. The glyphosate resistant crop technology for weed control in major agronomic crops such as corn, soybean and cotton was, as mentioned in hearing testimony, the most rapidly accepted new agriculture technology ever by farmers, for the simple reason that it worked so well. By being such an effective weed management tactic, many people thought that the technology was infallible and would always work regardless of how repeatedly it was used over years and within crops. The basis of sustainable weed control with or without herbicides is to use multiple tactics but with a herbicide as effective as glyphosate, the tendency was to use this as the sole tool until it doesn't work anymore. In fact, glyphosate does still work very well in most instances. The reports of 11 million acres infested with glyphosate resistant weeds are stark if taken out of context. There are reports of some weeds that are no longer controlled but this does not mean that the entire 11 million acres are completely covered with such weeds. The mere presence of a few weeds resistant to glyphosate is, of course, a matter of concern. This emphasizes that a return to multiple tactics (integrated weed management) including use of additional herbicides in combination with glyphosate and use of appropriate crop rotation and cultural weed management, are required for acceptable weed control. This integrated approach has always been necessary, as research has shown, but as

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we mentioned at the hearing, not always followed by weed managers due to the effectiveness of this single glyphosate tool.

b. If not, what are the influences acting on farmer weed management decisions? For instance, what role, if any, do contractual obligations with genetically engineered seed companies and the price of genetically engineered seed, play in the weed management decisions made by farmers?

There are several influences affecting farmer use of herbicides within their fields. Glyphosate resistant weeds allowed farmers to widely adopt no-till and minimum tillage approaches to weed control. These approaches resulted in reduced soil losses and reduced possibility of herbicide movement to water and overall reduced crop management costs (due to fuel savings and less tractor movement within fields during the season). The glyphosate resistant crop/weed management system was easy. Farmers could use glyphosate as a burn-down herbicide prior to or at crop planting and then return with one or two additional glyphosate treatments within the season to manage weeds. This was not only easy but saved money for the farmer. I am not sure exactly what the contractual agreements with farmers entailed from the standpoint of whether they were required to use a specific amount of glyphosate or the company brand of glyphosate within their crops, as the contracts may vary between companies offering the technology. I do know that there was a requirement that no seed could be saved from year to year. The requirement of no seed saving would force the farmer to buy new glyphosate resistant seed each year if they wanted to continue using this weed management technology. A return to non-glyphosate resistant crop seed would result in a necessity to integrate multiple tactics for weed management, break the cycle of continuous glyphosate use over years and, in fact, be closer to what is required for sustainable weed management. I would add that the same approaches of weed management tool integration within the glyphosate resistant crop system could be used but costs would increase.

2. We received testimony that a number of chemical manufacturers have petitioned USDA for deregulation of variants of soy, cotton and corn that have been genetically engineered to be tolerant of a number of existing herbicides. One of those petitions (10-188-01p) concerns a soybean designed to be tolerant of the herbicide Dicamba.

   a. Please elaborate on your experience with and knowledge of Dicamba, with particular respect to the impact on horticultural crops.

   My experience with dicamba in vegetable crops has involved multiple years of testing their response to low doses of dicamba sprayed at various times during the season and the subsequent effect on vegetable crop growth and yield. These studies have been conducted to determine the potential injury on vegetable crops to off-site movement of dicamba. Crops tested have included tomatoes, eggplant, pepper, broccoli, cauliflower, watermelon, muskmelon and squash. Since dicamba is a broadleaf weed killing herbicide, all these vegetables could be injured by off-site movement of this herbicide into vegetable fields.

Dicamba, as with any herbicide, can drift off-site but depending on the formulation used and its vapor pressure; a particular dicamba formulation may be more or less susceptible to volatility. Dicamba is sold in several different formulations. The original formulation was sold as the herbicide Banvel which is a dimethylamine salt of dicamba (3, 6-dichloro-o-anisic acid) formulation. The more common formulation now used is Clarity which is the diglycolamine salt of dicamba and a third product is Distinct which contains a sodium salt of dicamba. The Banvel formulation can volatilize, the Clarity formulation is much less volatile but volatility can occur, while the Distinct formulation has very low volatility potential. In terms of weed control, Banvel and Clarity provide best overall control of weeds.

The fear from off-site movement of any herbicide includes drift which is affected by many factors including wind movement, if application is done under high winds, spray droplet size and spray volume. Volatilization relates to the vapor pressure of the chemical and can result in movement after application but is usually dependent on environmental conditions such as temperature, humidity and fog or temperature inversions.
The potential damage from off-site movement of dicamba to vegetable crops is a major concern. All the crops I have tested are quite sensitive to low rate (herbicide amount) applications of the Clarity formulation. I used Clarity in my experiments because at this point, it appears to be the formulation that would be labeled for use in any released GMO crops containing dicamba resistance genes.

The experiments I conducted simulated how various rates of dicamba ranging from a labeled use rate to a very low concentration would cause crop injury and affect yield. The results, in general, were that dicamba can cause significant injury to the vegetable crops tested in terms of leaf growth malformation and effects on total yield and time when fruit matures. Crops that were most sensitive were tomato and muskmelon; however, all crops did show initial negative response to even extremely low rates.

In terms of these results, I feel that there is a significant potential for injury to most vegetable crops I tested, if dicamba moves off-site. I feel that drift is the biggest concern; however, drift would tend to be more localized near the field edges adjacent to where the dicamba application occurred. The source of the dicamba drift injury can, in most cases be identified, and if necessary, the person at fault identified. In terms of volatility, this is much more difficult to measure in terms of total injury effect as volatility would result in scattered injury. The source of the original application that resulted in volatility would be much more difficult to pin-point as volatility may not move in any logical direction.

c. Please share with the subcommittee your view as to the likely trend in Dicamba usage should a Dicamba-tolerant soybean be deregulated by USDA. In the context of that trend, please discuss the challenges to prevent unintentional damage to horticultural crops.

   I feel that dicamba usage would increase if resistant cultivars of soy were released. The applications would most likely be combined with glyphosate as a tool to manage any weeds that were resistant to glyphosate or always troublesome. I do not feel that all growers would choose this technology since, regardless of any claims; dicamba does not control the spectrum of weeds which glyphosate controls or has the same effectiveness on large weeds as glyphosate. In other words, dicamba use would not be on as many acres as the present acreage where glyphosate is used, as it would not always be necessary. Whether the only GMO crops released would contain both glyphosate and dicamba resistance genes is not known but I would hope, if this technology reaches commercialization, that growers would have a choice.

   In terms of unintentional damage from dicamba to horticulture crops, I feel certain registration and label restrictions would be necessary prior to such crop release. First, the potential volatility potential of the formulation of dicamba used in crops would need to be known. There are suggestions from the chemical companies developing this technology that volatity would not be a concern based on the formulation used in these crops. This would need to be proven completely. Secondly, any formulation of dicamba with volatility potential should not be allowed to be used. "How do you prevent this ?" is a good question since the other formulations with volatility potential are still on the market? The use of such formulations in the GMO crop would be a violation of the label (law) but this might be difficult to enforce. In terms of drift, this is a potential problem for almost any herbicide if improperly applied. The use restrictions on the application as stated on the label would need to be clear regarding application technology that minimizes drift potential. Such restrictions would minimize off-site movement to sensitive crops and potentially greatly reduce damage potential from dicamba use. There might also be considerations of not allowing dicamba use in areas of high concentration of horticulture crops. Although not asked, other horticulture crops including fruits, ornaments and landscape plants would need to be considered when using these herbicides.

d. In your opinion, will public education adequately prevent the potential damage to horticultural crops that you foresee?

   Public and farmer education would help dramatically. I am a firm believer that education, based on research results is the best approach to an informed clientele. However, in the case of dicamba use, I feel that label restrictions on use and requiring specific application technology and methods and conditions when the applications can be made, are essential to minimize potential off-site movement.

e. Does the existing biotech regulatory framework at USDA enable the agency to prevent the damage for horticultural crops you have already identified?

I feel that the current regulatory framework, if appropriately applied, would allow the dicamba resistant crops to be adequately tested for effectiveness. I feel that in addition to this regulatory framework, the EPA must also become involved in labeling the herbicides and approving any label in terms of their use prior to any final field use approval. Such a requirement would be necessary so herbicide use in these crops would minimize any off-site movement and damage to susceptible crops

3. Herbicide resistance in weeds is not a new phenomenon, of course. However, in testimony and in the popular press, glyphosate resistance in weeds growing in cotton fields in Georgia and elsewhere has been likened to an industry threat. Can you provide any examples of past herbicide resistant weeds that threatened entire agricultural sectors?

I do not feel there has ever been a case of herbicide resistance in weeds that threatened an entire industry and this includes the cotton situation with glyphosate resistant weeds. In all cases of herbicide resistance in weeds and specific cropping situations, the use of multiple tools including herbicides, crop rotation, non-chemical methods such as tillage and cover crops have been used to deal with resistance to a particular widely used herbicide. Such tactics allow continued acceptable weed management.

The best previous example of herbicide resistance where a widely used group of herbicides resulted in resistant weed evolution was with the acetolactate synthase inhibiting herbicides that are widely used in almost all agronomic and non-cropland situations. These herbicides were widely used, often in many cases, as has been seen with glyphosate, as the primary herbicide tool. As always happens with single method controls or tools that are repeatedly used within years and over years, weed resistance occurred. Although this restricted the initial effectiveness of the ALS herbicides, the use of integrated weed management including the use of other herbicides in combination allowed the continued use of the ALS herbicides and allowed acceptable weed control. These herbicides are still widely used in all of the crop and non-crop situations mentioned.

I feel the real difference in the glyphosate resistance situation is that the majority of agriculture acres of cotton, corn and soybean are glyphosate resistant and therefore, glyphosate is used on almost all cropland at least once and often times, repeatedly within the crop year and over years. The second change from previous weed resistance and cropping situations is that agronomic practices changed with the release of glyphosate resistant crops, especially regarding no-till, planting techniques and minimum use of tillage in crop. This was the result of the initial effectiveness of glyphosate in controlling most all weeds after they emerge, eliminating the need for tillage. A third result was that glyphosate was so widely used that several other previously registered herbicides, especially in cotton, were either not reregistered with EPA or they were removed from the market. This greatly limited the potential use of mixtures of herbicides within crop and also resulted in a much reduced variety of herbicide mechanisms of action. Such a result in cotton with herbicide availability, which is not the case in corn and soybean, has limited chemical approaches to weed management. This will require a return to other weed management practices that are integrated into cotton production to maintain acceptable weed control.

As mentioned in my testimony in July, additional research is needed on how best to use the weed control tools available to maintain sustainable and environmentally acceptable weed management. This research needs to be combined with educational programs on appropriate weed control practices. We cannot continue to rely on single tactic weed management programs. They have never worked in the long-term and will not work in the future. Changes away from the high level of reliance on only glyphosate for weed management will require some readjustment in design of control programs which will include more widespread readoption of integrated weed management.

Chairman Kucinich, I appreciate the opportunity to provide additional answers to your questions related to weed resistance in herbicides and 'superweeds' both in these written answers and also at the Domestic Policy Subcommittee meeting on July 28, 2010. Please contact me if you need further answers or clarification on the responses in this letter. I appreciate your work on the 'superweed' issue and your concern that the American farmer is allowed to remain the dominant force in producing food for the United States and the world.

Sincerely Yours,

Stephen C. Weller

Stephen C. Weller
Professor
Purdue University

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August 4, 2010

Mr. Troy Roush
10180 East 700 N
Van Buren, IN 46991

Dear Mr. Roush:

In connection with the July 28, 2010 hearing of the Domestic Policy Subcommittee hearing, entitled, "Are 'Superweeds' an Outgrowth of USDA Biotech Policy," I hereby request that you provide answers in writing to the following questions for the hearing record.

1. We received testimony that up to 11 million acres of American farmland are now infested with weeds exhibiting resistance to the herbicide glyphosate. We also heard testimony that such infestation occurred over a relatively short period of time, between 10 and 15 years.
    a. In your opinion, as a farmer, is it fair and accurate to characterize the proliferation of glyphosate resistant weeds in millions of acres of American farmland as a problem caused by a few bad actors – farmers who demonstrated reckless disregard for the rules and mores of farming?
    b. If not, who is responsible for the proliferation of herbicide-resistant weeds in fields growing genetically engineered, herbicide resistant crops? What are the influences acting on farmer weed management decisions? For instance, what role, if any, do contractual obligations with genetically engineered seed companies and the price of genetically engineered seed play in the weed management decisions made by farmers?

2. We received testimony that a number of chemical manufacturers have petitioned USDA for deregulation of variants of soy, cotton and corn that have been genetically engineered to be tolerant of a number of existing herbicides. One of those petitions (10-188-01p) concerns a soybean designed to be tolerant of the herbicide Dicamba. In your testimony, you spoke about the volatile nature of Dicamba.
    a. Please elaborate on your experience with Dicamba, with particular respect to environmental impacts from its use.

Mr. Troy Roush
August 4, 2010
Page 2

a. Please elaborate on your experience with Dicamba, with particular respect to environmental impacts from its use.
b. Please share with the subcommittee your view as to the likely consequences to farming should a Dicamba-tolerant crop be deregulated by USDA.

The Oversight and Government Reform Committee is the principal oversight committee in the House of Representatives and has broad oversight jurisdiction as set forth in House Rule X. An attachment to this letter provides information on how to respond to the Subcommittee's request.

We request that you provide these answers in writing as soon as possible, but in no case later than **5:00 p.m. on Wednesday, August 25, 2010**.

If you have any questions regarding this request, please contact Jaron Bourke, Staff Director, at (202) 225-6427.

Sincerely,

Dennis J. Kucinich

Dennis J. Kucinich
Chairman
Domestic Policy Subcommittee

cc: Jim Jordan
Ranking Minority Member

HOUSE COMMITTEE ON OVERSIGHT & GOVERNMENT REFORM
SUBCOMMITTEE ON DOMESTIC POLICY

ARE SUPERWEEDS AN OUTGROWTH OF USDA BIOTECHNOLOGY POLICY

Answers to the Committee: TROY ROUSH
August 24, 2010

1.a. Farmers wear a lot of hats, we are in affect the general managers of our businesses. There's a saying often heard in agricultural communities "jack of all trades master of none". We have to rely on experts in their respective fields to advise us, whether it be Accounting, marketing, technology, agronomy or even the selection of proper herbicides. You cannot point a finger at farmers for the overuse of classes of herbicides unless you first examine the advise farmers receive from advisors.

b. Those who have advised farmers on the overuse of single classes or modes of action of herbicides are clearly responsible and in the case of Glyposate resistant weeds. Those people would be the District sales managers and weed scientist working for Monsanto. Glyphosate (Roundup Ready) tolerant seeds come at hefty premiums, the only way for farmers to mitigate that cost is to use the low cost herbicide those seeds are engineered to tolerate (Glyphosate). In the case of contractual (Roundup Ready) seed production (when I was growing seed beans) farmers were only permitted by Monsanto, to use branded Roundup, herbicide and nothing else on that crop. I am relatively sure I still have copies of those contracts.

2.a. Dicamba, is extremely volatile. Many herbicides will move off the site of application if they are applied in a careless manner, such is in high winds and or using the incorrect nozzles and pressures. But these issues can all be controlled with good application management. Dicamba however is very different, Dicamba is actually more dangerous when applied under what for nearly all other herbicides is ideal conditions because at least a blowing wind would have the opportunity to dilute the Dicamba. Dicamba, during a calm hot day or a day with a slight inversion can volatize, raise up from the crop it was applied to and literally move in the slight breeze of the day and set back down latter in the day as the air cools. Dicamba is a very effective herbicide and will ruin most fruits and vegetable plants, it's also hard on ornamental plants and landscaping I've even seen it damage establish hardwood tree's. Fortunately because of these issues farmers rarely use Dicamba, and when we do we are careful to use it in the early spring or fall when the lack of susceptible plants and cooler environmental conditions keep volatization to a minimum.

b. Dicamba, would be an excellent solution to the problem of Glyphosate tolerant weeds were it not so volatile. If Dicamba-tolerant soybeans were deregulated the technology would be rapidly adopted by farmers, Dicamba, is a inexpensive and effective compound. And if your neighbor is using the technology then you will have to also or risk having your soybean crop damaged, further once the potential issue of Dicamba damaging soybeans is no longer a factor farmers have no reason not to go back using Dicamba on their corn crops again also. As I stated in my earlier testimony I am a tomato farmer with over 300 acres and also have certified organic grain production. Both enterprises would be in jeopardy, I'm fairly

confident the deregulation of Dicamba-tolerant soybeans will be the end of my tomato enterprise. I've had considerable damage to my tomato crop already from what could be described as a very isolated use of Dicamba two years ago by a neighbor. As for the organic grain segment of my business I can only speculate that if a inspector saw Dicamba herbicide drift on my crops my organic certificate would be suspended. I believe, based on past experiences the deregulation of Dicamba-tolerant soybeans would in fact ruin the two most profitable segments of my business.

Thank-you for the opportunity to answer these very important questions. I'm grateful to the committee for considering these issues that will affect my and many others farms as well as homeowners, gardeners and pretty much anyone who eats.

Sincerely,

Troy Roush

ONE HUNDRED ELEVENTH CONGRESS

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August 5, 2010

Mr. Micheal Owen, Ph.D.
Associate Chair and Professor of Agronomy
Department of Agronomy
Iowa State University
3218 Agronomy Hall
Ames, IA 50011

Dear Dr. Owen:

In connection with the July 28, 2010 hearing of the Domestic Policy Subcommittee hearing, entitled, "Are 'Superweeds' an Outgrowth of USDA Biotech Policy," I hereby request that you provide answers in writing to the following questions for the hearing record.

1. The glyphosate-resistant (GR) weed data in Table 1 of your testimony, reproduced from the 2010 NRC report) do not match the current listings on the weedscience.com website. For GR Palmer amaranth, you list five states and 200,000 to 2 million acres infested, while the current listings show nearly twice as many (nine) states and double the acreage (401,000 to 4.01 million acres) infested. Similar disparities for GR horseweed and tall waterhemp also exist. Can you explain the reasons for these substantial discrepancies? What, if anything, does it say about the rate at which GR weed populations are evolving or propagating?

2. What is the most accurate measure of the adverse impact of herbicide resistance in weeds? Please comment generally on the importance of the number of acres infested with weeds resistant to a given herbicide (or family of herbicides) versus number of resistant species, as a measure of the impacts of resistant weeds on herbicide use, the environment and farmer production costs. For instance, you cite 38 species of weeds that have evolved resistance to ACCase inhibitor herbicides, versus just 19 for glyphosate, yet according to the weedscience.com website, the aggregate acreage infested with GR weeds is many times that infested with ACCase inhibitors.

Dr. Micheal Owen
August 5, 2010
Page 2

3. In your testimony, you discuss the problem of glyphosate resistance in weeds, as you note in Table 1. Will you also discuss the impacts on farmers of weed shifts to more glyphosate-tolerant species, such as those listed in Table 2 of your testimony?

4. As you noted in your testimony, crops genetically engineered to be resistant to synthetic auxin herbicides, among others, are nearing commercialization. Two such traits are resistant to 2, 4 D and dicamba. Under certain circumstances, both herbicides have been known to revolatilize and drift after application, damaging neighboring crops and other plants. Please comment on the potential for crop damage with use of crop systems involving resistance to these herbicides.

5. Your testimony discusses the use of multiple herbicides with different modes of action, either sequentially or in mixtures, as one measure to forestall or mitigate herbicide-resistant weeds. Please comment on the risk of selecting for multiple herbicide-resistant weeds, via metabolic degradation, enhanced metabolism or other mechanisms?

6. You make the point that "unless growers collectively adopt more diverse weed-management practices, individual farmer's actions will fail to delay herbicide resistance to glyphosate because the resistant genes in weeds easily cross farm boundaries." Given the failure of voluntary stewardship programs and extension advice to stem or slow the emergence of glyphosate-resistant weeds thus far, what concrete measures could be taken to ensure that growers collectively adopt more diverse weed management practices? Is there a way to ensure a "level playing field" such that the efforts of growers who take the time and expense of proper stewardship are not undermined by less responsible growers? What, in your view, could the federal government do to help farmers and weed scientists better forestall and mitigate herbicide-resistant weeds and their impacts?

7. Isn't it true that the adoption of GR crops drives increased overall herbicide use, not only in GR-cotton and soy but corn as well? For instance, you mention that overall per acre herbicide use has decreased on corn from 1996 to 2007, in contrast to the trends in soybeans and cotton. Given the fact that glyphosate-resistant corn was not introduced until 1998 and, as shown in Figure 3 of your testimony, was adopted much more slowly than GR soybeans and cotton (Figures 1 and 2), reaching at most 11% of all corn acres in 2002, please explain the increasing overall herbicide use on corn from 2002 to 2007.

8. It is commonly asserted that glyphosate exhibits a low toxicity to mammals, birds and fish and that it kills most plants without substantial adverse environmental effects. Does the science substantiating those assertions apply only to the active ingredient, glyphosate, or to the glyphosate formulations normally used by farmers (such formulations usually contain additional ingredients, such as surfactants and other inert ingredients)? Are you aware of any scientific studies showing that POEA-containing Roundup formulations are lethal to the tadpole and adult stages of certain amphibian species at field-relevant usage rates?

Dr. Micheal Owen
August 5, 2010
Page 3

9. In your testimony you observe that the "adoption of glyphosate-resistant crops facilitated production success when using no tillage practices." Given the substantial adoption of no-till and conservation tillage production before the adoption of GR crops, what other factors drive adoption of these practices?

10. In your testimony you state that increasing herbicide usage on soybeans and cotton from 1996 to 2007 was the result of the rapid adoption of glyphosate-resistant crops, and the accompanying displacement of lower-dose herbicides by higher-rate glyphosate. Are there any other factors, such as increasing glyphosate use in response to glyphosat resistance in weeds, driving this increased glyphosate use?

The Oversight and Government Reform Committee is the principal oversight committee in the House of Representatives and has broad oversight jurisdiction as set forth in House Rule X.

We request that you provide written answers to these questions as soon as possible, but in no case later than **5:00 p.m. on Thursday, August 26, 2010**.

If you have any questions regarding this request, please contact Jaron Bourke, Staff Director, at (202) 225-6427.

Sincerely,

Dennis J. Kucinich

Dennis J. Kucinich
Chairman
Domestic Policy Subcommittee

cc: Jim Jordan
Ranking Minority Member

Follow up questions from the 28 July 2010 Domestic Policy Subcommittee hearing

"Are 'Superweeds' and Outgrowth of USDA Biotech Policy?"

Submitted by

Micheal D. K. Owen
Associate Chair and Professor of Agronomy
Agronomy Department
Iowa State University
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1. The disparities between Table 1 offered as evidence during the testimony and the current numbers of glyphosate-resistant weeds, states with glyphosate-resistant weeds and area infested with glyphosate-resistant weeds reflects several aspects about how the website (www.weedscience.org) is maintained:
   a. Submissions to the website are voluntary from objective parties, typically university weed scientists and agronomists. These submissions occur in real time and the website keeps a running tally so data today may be different than the data that is available tomorrow.
   b. The discrepancies reflect the dynamic nature of the evolution of resistance to glyphosate, but also the recognition of these populations by scientists. As I indicated in my testimony, the evolution of resistance to glyphosate in weeds is increasing at an increasing rate.
2. The most accurate measure of the adverse impact of herbicide resistance in weeds is the increased cost of managing the herbicide resistant weeds. Obviously, the greater the number of species with evolved resistance and the greater the acres infested, the greater the economic impact. However, it is important that some weeds (which are ecologically adapted to the crop production systems) are more prevalent and thus with evolved herbicide resistance, will be of more economic consequence. Weeds such as common waterhemp (*Amaranthus tuberculatus*) were widely distributed in Midwest agriculture prior to the evolution of glyphosate resistance. Thus, they were already of economic importance; the evolution of glyphosate resistance increases the economic costs because control tactics are more expensive not because the glyphosate-resistant biotypes are more competitive.
3. The impact, in a general sense, of a weed shift resulting in increased populations of naturally glyphosate-tolerant weeds would be similar to the impact of weeds with evolved resistance to glyphosate; the cost of management increases. Again, the relative ecological adaptation, and

thus level of distribution, would directly affect the economic consequences. The more widely distributed a weed is, the more costly it becomes to agriculture.

4. As the question suggests, some of the synthetic auxins (i.e. dicamba) have, because of the physicochemical characteristics of the active herbicide ingredient, the potential to change physical state (volatilize) from a liquid or crystal state to a gaseous state. Drift from volatilization is typically less physiologically damaging the direct spray drift on non-target plants. However the relative sensitivity of the non-target plant will dictate the relative impact of the damage as will interactions with environmental conditions. Furthermore, some damage while not physiologically important (i.e. crop yield is not reduced) may dramatically impact the value of the crop (i.e. the aesthetic quality of a vegetable may be compromised and thus the value of the crop reduced). The potential damage from crop systems utilizing these herbicides will be similar to the damage that occurs currently when these herbicides are used in weed management. However, given that the application frequency will likely be increased, the area treated larger than currently treated, and the applications may occur later in the growing seasons when environmental conditions and presence of susceptible non-target plants must be considered, the resultant drift/damage may be greater with the crop systems including resistance to synthetic auxin herbicides when compared with current use of synthetic auxin herbicides.
5. Weeds with evolved resistance to multiple herbicide mechanisms of action are already present in some agronomic situations. In rare instances with specific weeds, the resistance is attributable to the evolved ability to metabolize the herbicide. However, most herbicide resistance in weeds is attributable to target site mutations, differential movement or other forms of resistance. The use of herbicide tank-mixtures could contribute to multiple resistances only if the components of tank-mixture provided equal selection pressure on the target weed. In truth, this question is extremely difficult to answer in brief and I have provided a cursory response.
6. The statement was somewhat simplified; certainly if one grower uses management that results in the evolution of herbicide resistance in a specific weed species, that trait may move to another field via pollen or seed (gene flow). However, if the other grower has proactively adopted mitigation tactics (i.e. BMPs), the impact of that gene flow will be minimal as the resistance biotypes will not increase in the field. Unfortunately, the only way I can see to "level the playing field" is to increase the research and education that provides the tactics to mitigate the problem. There are models that suggest a grower will not recognize that herbicide resistance in a weed population until 30% of the population is resistant. I suggest that this same "threshold' might be in effect for getting growers to respond/react; when resistance is an issue for 30% of the growers, the rest will change their practices. **(please recognize that this is only speculation on my part)** Regardless, currently public support for weed science is non-existent for research and minimal/declining for outreach/education. We are not able to provide growers with information about the mitigation tactics in sufficient frequency to affect changes. Regulations are not an option. Thus, the way the federal government might help resolve this critically important agricultural problem is actively fund and promote the importance to weed science and to keep as many alternative tools available (i.e. existing and new herbicides).

7. The assessment of herbicide use depends on the metrics. The number of herbicides typically used in corn, cotton and soybean has declined with the adoption of glyphosate-resistant crops. The number of applications per crop per season has likely remained steady or increased. The actual amount of herbicide a.i. per acre has likely increased due to the fact that the a.i. application rates of herbicides that glyphosate replaced were considerably lower than the rate that glyphosate is applied.
8. The question is not within my expertise. I cannot comment on the toxicological characteristics of herbicides other than to suggest that the EPA has indicated through the use of the signal word that glyphosate is a very safe herbicide. I am aware, however, of scientific studies that claim glyphosate is a toxicological problem. However the studies that indicate that glyphosate is not a toxicological problem are considerable more prevalent than those publications that suggest otherwise. Again, I cannot evaluate the science behind the reports.
9. There are several factors that have contributed to the adoption of conservation tillage including no tillage systems. A major factor was the farm bill. Also, the availability of effective herbicides for control of weeds. Recognize that weeds represent the most important pest complex to all agricultural systems (but to reiterate the most underfunded pest management group). Thus, success in managing weeds in conservation tillage will allow growers to adopt these practices. Conservation tillage has other benefits to growers; less machinery, fewer trips across the field (better time utilization), and lower fuel costs to mention a few. Given the vertical integration of farms (fewer farmers, larger farms, greater distances between farms), any production practice that allows growers to be more efficient will be widely adopted.
10. Glyphosate use increased for a number of reasons; effectiveness of the product, simplicity of use, convenience, and others. Also important was the reductions in the cost of glyphosate and the grower perception that weed control using glyphosate was lower in cost compared with other systems and tactics. With the evolution of glyphosate resistance in weeds, many grower increased the use rates and application frequencies but without success. In fact, these latter responses actually exacerbated the problems.

ONE HUNDRED ELEVENTH CONGRESS

Congress of the United States
House of Representatives

COMMITTEE ON OVERSIGHT AND GOVERNMENT REFORM

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August 6, 2010

Mr. David A. Mortensen, Ph. D.
Pennsylvania State University
422 Agricultural Sciences and Industries Building
University Park, PA 16802

Dear Dr. Mortensen:

In connection with the July 28, 2010 hearing of the Domestic Policy Subcommittee hearing, entitled, "Are 'Superweeds' an Outgrowth of USDA Biotech Policy," I hereby request that you provide answers in writing to the following questions for the hearing record.

1. Herbicide resistance in weeds is not a new phenomenon, of course. However, in testimony and in the popular press, glyphosate resistance in weeds growing in cotton fields in Georgia and elsewhere has been likened to an industry threat. Can you provide any examples of past herbicide resistant weeds that threatened entire agricultural sectors? Are there any other ways in which glyphosate resistance is a unique problem, distinguishable from past examples of herbicide resistance in weeds?

2. During your testimony you alluded to the role that government regulation could play in helping mitigate the glyphosate resistance problem and future herbicide resistance problems. Could you expand on the kind of regulations you believe would be effective in this regard?

The Oversight and Government Reform Committee is the principal oversight committee in the House of Representatives and bas broad oversight jurisdiction as set forth in House Rule X.

We request that you provide written answers to these questions as soon as possible, but in no case later than **5:00 p.m. on Wednesday, August 25, 2010**.

Dr. David A. Mortensen
August 6, 2010
Page 2

If you have any questions regarding this request, please contact Jaron Bourke, Staff Director at (202) 225-6427.

Sincerely,

Dennis J. Kucinich

Dennis J. Kucinich
Chairman
Domestic Policy Subcommittee

cc: Jim Jordan
Ranking Minority Member

Date: August 18, 2010

TO: Dennis J. Kucinich, Chairman, Domestic Policy Subcommittee

FROM: Dr. David A. Mortensen

SUBJECT: Written response to several additional questions regarding glyphosate resistant crops and their regulation

What is unique about the glyphosate resistant weed problem, we have known about herbicide resistance for some time.

I'd like to clarify what I believe is a very important point. During the July 28, 2010 hearing, at least one member of our five member panel stated (and I'm paraphrasing) "herbicide resistance isn't new and there's little unique about glyphosate resistance". I believe this perspective is ill-informed and misleading. Glyphosate resistant soybean, cotton and corn were once highly sensitive to glyphosate, were genetically transformed, and are now resistant to the herbicide. The genes conferring resistance to glyphosate that have been introduced into these crops are patent protected. Therefore, for the first time, seed (and an associated technology fee) and herbicide are sold as a package. Effectively, when farmers buy the seed they are buying the package. As a result, the proportion of cropland acres that are treated with glyphosate is far higher than any other herbicide active ingredient. Also, the number of acres where glyphosate is used in consecutive years is higher than any other herbicide. As a result, the selection pressure for herbicide resistant weedy biotypes and species (and acres infested by them) is far more severe than any we have seen in U.S. agricultural production. The resulting glyphosate resistant weed problem is said to threaten entire agricultural sectors. For example the glyphosate resistance problem in Georgia alone is now estimated to exceed one million infested acres.

It is obvious that herbicide manufacturers and seed companies are concerned about the problem of glyphosate resistance as they are investing hundreds of millions of dollars to add additional herbicide resistance genes that will enable combinations of herbicides to be applied to glyphosate resistant crops. This industry response is unique to glyphosate resistant crops and is being mounted to address the glyphosate resistant weed problem.

Could you expand on the kind of regulations you believe would be effective in mitigating the glyphosate resistance problem?

Regulation could take a number of forms. First, environmental market incentives should be implemented to encourage farmers (possibly through the farm bill) to adopt a broader integration of tactics for managing weeds. Increasingly, farmers are adopting cover crops, crop rotations and novel selective methods of cultivation for weed suppression. Such practices would go a long way toward reducing the selection pressure for glyphosate resistant weeds. Second, limit the registration and commercialization of additional glyphosate resistant crops. As indicated earlier, each additional crop increases the number of acres treated and the number of acres treated in consecutive years with glyphosate. Third, during the registration process, the EPA and APHIS should work together to detail then require implementation of a herbicide resistance management plan at the individual farm level. Such a plan should limit repeated us of herbicides in ways that select for resistance or that result in increased reliance on greater amounts of herbicide to achieve weed control. In the same way that Bt or nutrient runoff is regulated at the farm level, it's entirely feasible to consider farm-level herbicide management planning to limit practices that accelerate herbicide resistance. Finally, when a new GE resistance trait allows for an old herbicide to be used in new crops, at new rates, and in novel contexts, EPA and APHIS should work in a coordinated way to insure that a thorough reassessment of the herbicide active ingredient occurs in the context of its expanded and novel use. This reassessment should include explicit consideration of weed resistance and should be regionally relevant and recognize the spatial heterogeneity of fields, farms, and crops produced.

Appendix 1. To the testimony of Dr. Dr. Stephen C. Weller, professor, Purdue University to the Domestic Policy subcommittee of the Oversight and Government reform Committee, July 28, 2010.

Title: Benchmark Study: Perspectives on Genetically-Engineered Glyphosate-Resistant Crops and the Sustainability of Glyphosate-based Weed Management*

Authors: Micheal DK Owen, Bryan G Young, David R Shaw, Robert G Wilson, David L Jordan Philip M Dixon and Stephen C Weller

Abstract

BACKGROUND: A six-state, four year field project was initiated in 2006 to study weed management methods that ensure the sustainability of genetically engineered (GE) glyphosate-resistant (GR) cropping systems. The Benchmark Study field-scale experiments were initiated following a survey (Benchmark Study Survey), conducted in the winter of 2005-2006, of farmer opinions on weed management practices and their views on GR weeds and management tactics.

RESULTS: The main survey findings considered in this perspectives paper supported the premise that growers were generally less aware of the significance of evolved herbicide resistance and did not have a high recognition of the strong selection pressure from herbicides on the evolution of herbicide-resistant weeds.

CONCLUSIONS: From our perspective, the results of the Benchmark Study Survey indicated that there are educational challenges to implement sustainable GR-based crop systems and helped guide the development of the field-scale Benchmark Study. Paramount is the need to develop consistent and clearly articulated science-based management recommendations that enable farmers to reduce the potential for herbicide-resistant (HR) weeds. Without a proactive and integrated educational approach to manage weeds in GE GR crops, wide-spread evolution of GR weeds is inevitable.

KEYWORDS

Glyphosate, glyphosate resistance, glyphosate-resistant crops, selection pressure, genetically engineered crops

*

This is a draft copy of a manuscript that has been submitted for publication.

1 INTRODUCTION

Global demands to produce more food has increased dramatically in a relatively short period of time and the ever-increasing global population has placed incredible demands on agriculture to produce sufficient yields thus avoiding "Malthusian" disasters in the future [1]. Ideally, increased yield will be achieved through sustainable but intensive production practices that allow dramatic increases in food while protecting aquatic and terrestrial ecosystems [2]. There are only two possible solutions in the immediate future to the dilemma of increasing requirements for food, biologically-based fuel and fiber; improve production efficiency on existing arable land or increase the land area under cultivation [3]. These two options have both benefits and risks that must be addressed. Improved efficiency on land already under cultivation represents the best option but does not represent a simple means to an end [2]. A longer term solutions to the global demands on agricultural production may be to improve crop genetic yield potentials, responses to stress and increased resources utilization efficiency. Genetically engineered (GE) crops are suggested to be an important tool that will allow improved yields and more efficient use of resources thus enhancing crop production efficiency while minimizing risks to the environment (e.g. soil erosion) [3]. One of the keys to improved crop production efficiency is the effective management of weeds, which are ranked as the number one crop pest by a majority of farmers [4]. This is no great surprise as weeds are constantly evolving within the man-caused agroecosystems by adapting to high selection pressures imposed by crop production practices [5]. While eradication of weeds represents the obvious way to eliminate some crop yield loss, the probabilities of accomplishing this goal are extremely unlikely given the ecological adaptability of plant species to fill niches created by agriculture, and the resource and technical issues that affect weed eradication [6]. Importantly, growers suggest that the factors that control the introduction, movement and selection of weeds are beyond their control despite the universal efforts expended on all arable land to mitigate weed infestations [7]. This perspective expressed by growers that external factors (i.e. management tactics practiced by neighbors) further complicates the ability to develop sustainable tactics to manage weeds within the prevailing crop production systems.

A telephone survey (Benchmark Study Survey) was conducted between November 9, 2005 and January 6, 2006 to describe and quantify the impact of the adoption of GE glyphosate-resistant (GR) crops by growers in Illinois, Indiana, Iowa, Nebraska, North Carolina and Mississippi[8]. The Benchmark Study Survey objectives were to assess production practices before and after the adoption of crop production systems based on GE GR crops and detailing changes in weed pressure, tillage, and herbicide usage in GE GR crop systems. Importantly, grower awareness of the risk and factors influencing the selection of GR weeds and their willingness and ability to implement changes in management tactics were determined. A sub-set of respondents to the telephone survey were selected to participate in the Benchmark Study, a multi-state, multi-year field scale assessment of the sustainability of crop production systems based on GR crops and glyphosate (see Shaw et al. in this volume). This perspectives paper discusses GE GR crops and the implications this technology has on the long-term sustainability of agriculture and specifically, our views on impacts that widely-used grower practices have on weed communities.

1.1 Background on Glyphosate-resistant Crop Systems

GEGR crops were commercially introduced in 1996 and have likely been the most rapidly and globally-accepted agronomic production practice in the history of agriculture [9]. Worldwide, the crops that have GE GR cultivars and represent the greatest planted area are corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.) and soybean [*Glycine max* (L.) Merr]; however a high percentage of sugar beets (*Beta vulgaris* L.) in the US and canola (*Brassica napus* L.) grown in North America are GE GR cultivars [10, 11]. Recently, a coalition of nine grain organizations from the US, Australia and Canada have agreed to support introduction of GR wheat (*Triticum aestivum* L.) thus potentially increasing the land area planted to GR crops[12]. Although data varies, there were a reported 114.3 million hectares of GE crops grown in 23 countries by more than 12 million farmers in 2007 [13]. Since 1996 more than 400 million cumulative hectares of GE crops have been planted in the US[14, 15]. In 2009, the National Agricultural Statistics Service (NASS) reported that 85% of corn, 88% upland cotton and 91% of soybean hectares were planted to GE varieties which include transgenic traits for Bt as well as herbicide resistance (Tables 1, 2and 3) [16].

Farmers in the US account for approximately 50% of the worldwide hectares of GE GR crops grown [13]. Rapid adoption of GE GR crops occurred because glyphosate is highly effective against almost all economically important weeds, weed management is simplified and its use facilitated widespread adoption of no-tillage systems that conserve both soil and energy resources. No-till systems in the US have increased from 15 million hectares to over 25 million hectares from 1994 to 2004, in part due to the availability of GE GR crops[17].

1.2 Benefits and Risks Associated with GE GR Crops

The benefits and risks of the globally-widespread adoption of GE GR crops on the agroecosystem and for society has been a contentious topic of debate in scientific journals and the popular media [18-21]. While adopters of GE GR crops experience pecuniary and non-pecuniary benefits such as highly reduced effort needed to implement a weed management system that significantly increases crop production, the risks as perceived by society, must also be given serious consideration[3, 22-27] Complexity of assessing benefits and risks of GE GR crops is great and results can demonstrate considerable variability depending on the specific GE cultivar, the production practices and the specific agroecosystem [28].

1.2.1 Benefits of GR Crops

GR technology has been adopted by farmers with, in most cases, a high level of satisfaction, implying great benefit [29]. Advantages from the adoption of GR crops include, but are not limited to the simplification of weed control, greater work flexibility and time management, improved success in conservation tillage production systems and favorable economic returns[30]. The environmental impact to GR crops and glyphosate is described as favorable when compared to "conventional" crop production systems (those using non-GR crops), specifically when soil erosion and water quality are considered [31]. Conservation tillage systems, particularly no tillage systems, are described to be more sustainable and environmentally benign, based on the potential for soil erosion and water quality, than crop production systems based on continuous aggressive tillage[32] and GE GR crops have facilitated more consistent management of weeds in conservation tillage systems, particularly winter annuals that were not previously controlled consistently and effectively. Furthermore, conservation tillage has concomitant benefits of reduced time required to produce crops, reduced use of petroleum fuels, reduced production of greenhouse gases (as well as enhanced carbon sequestration in no-tillage systems), improved soil biological health, improved soil physical health and reduced soil erosion[32, 33]. Society also experiences these benefits attributable to the adoption of GE GR crops.

The favorable economics of GR crops is a major benefit and an important consideration for growers[30, 34]. Actual production costs and yields will vary depending on the specific crop and may not always favor the GE GR cultivars [35, 36]. When economics are considered at the farm enterprise level, including the non-pecuniary benefits such as time management, simplicity, and environmental improvement, the GE GR cultivars are strongly favored when compared with conventional crop cultivars [30, 34-36].

1.2.2 Risks of GE GR crops

The weed resistance issue and societal concerns associated with GE GR crops, including alleged small farmer displacement and food safety concerns, GE pollen movement to wild species, volunteer GE GR crops and other issues, have been the focus of many scientific publications[37-43]. However, these publications do not definitively characterize or bring resolution to the issues. There is greater and likely more contentious debate in Europe than in the US, however there continues to be concerns about GE GR crops expressed by groups within the public sector wherever they are grown. It is clear that these public groups perceive the risks of GE GR crops to the environment and food safety differently than many scientific experts [42]. The occurrence of GR weeds and the rare discovery of GE crops not approved for human consumption in the commercial food chain has at times increased public fears about the ability of the industry to regulate GE crops effectively [41]. However, these fears are not realized as commercial agriculture has done a good job with regard to the utilization and handling of GE crops.

From an actual scientific perspective, potential risks associated with cultivation of GE GR crops can include effects on ecosystems such as decreased species biodiversity, weed spectrum shifts, and the likelihood that weeds will evolve resistance to glyphosate if it is the only product used[44-47]. It is important to recognize that these risks are no different for conventional crops and all herbicides. The risks are driven, in part, by ecological factors (i.e. species biodiversity) but influenced by agricultural practices such as tillage and herbicide use [48-50]. However there is not a clear direct effect of GE GR crops on these ecological changes and it is likely that any effect of GE GR crops is confounded by other agricultural practices (e.g. tillage) [31]. Interestingly, the predictions of the impact of GE GR crops and management tactics on biodiversity and actual occurrence have not always been in agreement. Watkinson et al. [47] predicted that weed populations would be significantly reduced or eradicated by GE GR crop production systems while Scursoni et al. [51] measured increases in the diversity of weeds attributable to the use of glyphosate in GE GR crops. However, "traditional" agriculture has significantly impacted biodiversity historically and these effects occurred irrespective of GE GR crops [52].

There has been conflicting opinions about risks attributable to GE GR crop systems and differing opinions are often supported by data published in peer reviewed scientific publications. However, many of the risks are based on opinions not supported by science; it is critically important to assess risks attributable to GE GR crops on solid, objective science. Purported risks attributable to GE crops, such as the impact that the transgenic traits have on ecosystems [53], soil microorganisms[54, 55], toxicological effects [18, 21, 56-59], social and socio-environmental implications [23, 60]} and introgression into land-race and near weedy relatives [61-63] have resulted in considerable debate and disagreement within scientific- and lay-communities [40, 64, 65]. In fact, there are concerns that GE GR technologies are subject to a negative bias in scientific publications [66, 67]. Often the published literature on the ecological, toxicological and environmental risks of GE crop systems is contradictory. For example the impact of GR crops and glyphosate on soil microorganisms is described negative in some publications[55] but favorable in many others[68-72]. Similarly, assessments of toxicological and ecotoxicological risks attributable to GE GR crop systems are often in conflict[56-58, 73]. Nonetheless, environmental, toxicological, ecotoxicological and numerous other studies were conducted as a requirement for registration by the United States Department of Agriculture (USDA) and the Environmental Protection Agency (EPA), both of whom determined that the GE products are safe for use. The industry supplying GE traits must also be aware and respond to legal challenges about the ecological impacts attributed to the technology [74]. Given the concerns, it is critically important to continue the science-based public debate surrounding GE GR technologies [75]. Importantly, a majority of scientific reports clearly demonstrate the benefits of GE GR technology as a means to increase global food production without negatively impacting the environment [38]. A key to resolving public fears is to identify the role of public debate and continue to provide objective information based on science describing the utilization of the technologies.

1.2.2.1 Evolved resistance to glyphosate

A primary concern for the long-term sustainability of the GR crop system is the extent that GR weeds will evolve or GR volunteer crops will become a pervasive weed problem and how utilization of additional tools for their control are incorporated into the system. Importantly, the evolution of resistance to herbicides in weed populations is not unique to glyphosate and was in fact predicted more than forty years prior to the wide-spread adoption of glyphosate [76]. Furthermore, predictions specifically addressing evolved resistance to glyphosate preceded the actual reports from the field [77]. University researchers, government agency officials and private sector life sciences companies agree that widespread adoption of GE GR crops and concomitant weed management practices has and will continue to change the abundance and types of weed species found in agronomic fields. The full implications of these inevitable changes in weed populations are, in part, a function of the current production practices and resulting changes are not ecologically different than changes that have historically occurred in response to other agricultural and weed management tactics[78]. Given the cumulative hectares of GE GR crops that have been planted in the US and the selection pressure imposed upon weed communities by the use of glyphosate, it is understandable that significant changes in the agroecosystem have occurred as the result of adopting GE GR crops and glyphosate as the primary if not sole tactic for weed control[14, 15, 79]. There is now general agreement that evolution (defined here as: changes in genotype frequencies that result from selection pressure on genetic variation within a population of a weed species) of GR weed biotypes was inevitable, although again some disagreement exists on the ultimate degree and nature of GR weed impact on agricultural practices [43, 80]. Currently 19 weed species have evolved resistance to glyphosate (Figure 1 and Table 4) [81]. The reported numbers are subject to frequent change. Eleven of these species are found in the US and eight of the GR weed biotypes evolved in conjunction with GR crops. Given the widespread adoption of GE GR crops (more than 80 million hectares in the US in 2009[11]) and the use of glyphosate, often as the only herbicide used, it is not surprising that the ecological risk of evolved glyphosate resistance has resulted in an increasing number of GR weeds that are evolving at an increasing rate (Figure 1).

The first GR weed in row crops identified in the US was horseweed [*Conyza canadensis* (L.) Cronq.], reported in Delaware in 2000, and its appearance was possibly correlated with the cultivation of GR soybeans [82]. Recently other GR weed populations have been reported (Figure 2 and 3, Table 4).All these weeds are major economic problems in agronomic crops in the corn, cotton and soybean growing regions of the US and the distribution of glyphosate resistance in these weeds is increasing. GR horseweed is now wide-spread throughout much the US cropland[81].

It is important to recognize that the impact of GE GR technology on weed communities is not directly attributable to the use of a GE GR crop, but rather an indirect effect of the management of the GE GR crop[78, 83] (e.g. how and which herbicide is applied) which is different from other GE crops (i.e. cultivars that include GE *Bt*). Specifically, the trait that confers resistance to glyphosate in crops does not, by itself, impart any selection pressure on the weed community. The selection pressure is imposed by the herbicide and is a factor only when the grower makes the management decision how and when to apply the herbicide. However, *Bt* trait in the GE crop exerts selection on the insect complex continuously. Regardless, the occurrence of evolved resistance to glyphosate in weed communities represents an important and escalating problem in global agroecosystems [84].

The speed and frequency of evolved glyphosate resistance in weeds likely reflects a lack of grower understanding about the influence that production practices, notably herbicide use, has on the composition of the weed community [85, 86]. A recent grower survey funded by BASF Crop Protection Corp. provided further insight into this problem [87]. The "2010 Weeds to Watch Poll" was distributed online to growers, retailers, distributors and university experts throughout the US. Weeds reported in the survey have either evolved GR populations or are known to be naturally tolerant to glyphosate [81, 88, 89].Survey responses suggested the primary weeds of concern in GR systems nationwide included common lambsquarters (*Chenopodium album* L.),horseweed, giant ragweed (*Ambrosia trifida* L.), waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer.), morningglory species (*Ipomoea* spp.) and Palmer amaranth (*Amaranthus palmeri* S. Wats.) . Responses from the Midwest were most common and respondents listed waterhemp as a "weed to watch" with common lambsquarters and ragweed species (*Ambrosia* spp.) listed as serious weed problems. Overall, respondents reported that glyphosate resistance in weeds was a major concern in GR crop systems.

To further gain insight into grower attitudes toward GR weeds evolution and management, another study involved a robust telephone survey conducted by Farm Progress Company for Syngenta Crop Protection Corp. on farmer concerns for GR weeds, specifically GR giant and common ragweed (*Ambrosia artemisiifolia* L.) (Figure 2 and 3) [90, 91]. The survey represented responses from farmers across the US, with the majority of responses from the Midwest, and suggested that grower awareness of the immediacy of the potential for evolved weed resistance to glyphosate was high and the need for appropriate management tactics great. These results agree with a previous study [92] and correlate the areas planted to GE GR crops (Table 1, 2 and 3).

2 FARMER STAKEHOLDER IMPACT ON GR CROP SUSTAINABILITY

The Benchmark Study Survey in 2005 was a robust and wide-scale assessment of the implications of farmer knowledge and attitudes on weed management in GR crops in US agriculture and showed at this time, farmers did not have a high level of awareness of the potential risks to the sustainability of the GR crop systems in regard to evolved glyphosate resistance. However, changes in the crop systems have occurred since the Benchmark Study Survey. Notably, the number of weeds with evolved resistance to glyphosate has increased from nine to 19 resulting in an escalation in presentations and information to growers about the implications of evolved resistance to glyphosate in weeds on the sustainability of GR systems (i.e. "The Glyphosate, Weeds, and Crops Series" [www.glyphosateweedscrops.org]) [93]. A survey of grower attitudes and awareness about the risks of evolved resistance to glyphosate conducted (being conducted now), after the increases in available information, should provide better information whether growers are aware of and implementing changes in management programs. Herbicide-use practices by growers in GR crops have also changed since the Benchmark Study Survey was conducted as the use of a soil-applied herbicide that provides residual weed control has increased in GR corn and soybean(Figure 4 and 5) [94]. Other studies provide support that growers are moving towards a better understanding of the implications of their herbicide-use practices and thus improved sustainability for the GE GR crops and glyphosate [29, 94, 95]. However, the general use of glyphosate as the primary if not sole weed management tactic is still prevalent in a number of crop systems.

2.1 Benchmark Study Survey Summary

The Benchmark Study Survey of farmers as described [86] consisted of questions about weed management practices, views and concerns on GR weeds and tactics used to manage the selection and spread of GR weed populations in GE GR crops. Briefly, the survey showed few farmers thought GR weeds were a serious issue and while more thought field tillage and/or using a non-GR crop in rotation with GR crops would be an effective strategy, there are still concerns about farmer perspectives about GR weeds. Additionally, many farmers did not recognize how recurrent use of an herbicide plays a role in the evolution of resistance in weed populations or how an agroecosystem dominated by glyphosate as the main weed control tactic facilitates GR weed population evolution[86, 94, 96, 97].

2.2 Considerations and Programs to Ensure Sustainability of Weed Management in GR Crop Systems

The Benchmark Study Survey results suggested several observations of farmer attitudes toward practices they might use to manage the evolution of GR weeds. It was noted that farmers with >200 ha were more concerned about GR weeds than those with <200 ha [97]. These observations were made in 2005 but it is still disturbing given the increasing number of instances of evolved GR weed populations in the US and the world[81]. It is widely accepted that the recurrent use of glyphosate will increase selection pressure for the evolution of additional GR weed biotypes. Thus, glyphosate effectiveness in GE GR crop systems is at serious risk unless programs are developed to effectively educate farmers and incent them to proactively choose weed management tactics that manage glyphosate resistance evolution.

When considering herbicide-based programs for managing weeds and preventing or minimizing the effect of GR weeds, there are numerous opinions on the best approach. For instance, Sammons et al. suggested the best method of herbicide resistance management is to have weed-free fields [98]. This is true from a theoretical resistance management perspective but is not usually either environmentally or economically practical; thus other management tools (i.e. other herbicides) must be used. Most current GR weeds have evolved a relatively low level of resistance to glyphosate [98]. It has been argued that low-level glyphosate resistance can be overcome by adjusting the rate of glyphosate applied. This approach would require farmers to adjust the glyphosate rate to target those weeds in their field in hopes of managing the evolution of GR weeds [98]. There is no scientific consensus that this approach is valid, and in fact there is documentation that increasing the rate of glyphosate may expedite the evolution of GR weeds where the resistance is controlled by a single partially dominant nuclear gene [99]. By using a herbicide rate (higher) that is discriminatory between susceptible and resistant biotypes, the population will shift towards resistance [100].

Even though a herbicide rate adjustment approach is easiest and may work to lessen the probabilities of herbicide resistance evolution in some weeds, the most sustainable and effective approach to GR weed management should include several tactics such as applying tank mixtures of herbicides with different mechanisms of action, tillage, crop rotation, and other integrated weed management approaches [98, 101, 102]}. As Sammons et al. point out, herbicide resistance in a few weed species to various herbicide types has not made herbicide use impractical or uneconomical [98]. Whereas this may be true, the evolution of herbicide resistance, particularly glyphosate resistance, could deplete management options for many problematic weeds and force growers to use more herbicides within a given crop to control a variety of weeds resistant to more than one herbicide[103]. The tank-mix approach appears to be favored by many farmers, but care must be used in following technical recommendations and choosing the specific tank-mix herbicides to avoid selecting for resistance of weeds to other herbicides and causing antagonistic interactions between herbicides that result in reduced weed control. Another important recommendation is to use a soil-applied herbicide(s) that provide residual control of the target weeds.

Another popular commercial approach that is now being considered to address weed resistance to herbicides is to switch to crops genetically engineered with resistance to another herbicide or stacked resistances to more than one herbicide. Considerable research to discover genes responsible for conferring resistance to an array of herbicides and then include these genes in crop cultivars by genetic engineering is ongoing [104, 105]}. GE crops with resistance to dicamba [104], glyphosate [106], glufosinate [107], 2,4-D [108], and acetolactate synthase inhibitors[109] are either commercially available or under development. The concept is that the use of GE crops resistant to multiple herbicides may allow better management of the evolution of herbicide resistance in weeds. However, when considering this approach, if only one herbicide becomes the sole tactic used for weed management, the use of GE crops with multiple herbicide resistance also may be unsustainable. Consider that many weed species have evolved multiple- and cross-resistance to herbicides that are widely used in the US [81]. The specific characteristics demonstrated by some weeds have that results in resistance to multiple herbicides and even the specific mechanism(s) of cross-resistance remain largely unknown. Furthermore, there has been no assessment of the actual risk of multiple herbicide resistant GE crops to agroecosystems. Consider that resistance to ALS inhibitor herbicides evolved quicker and more widespread than resistance to glyphosate. The evolution of herbicide resistance in weeds is not the result of GE crops but rather the management decision to use a single mode of herbicide action as the primary or sole tactic to control weeds. Multiple herbicide resistant GE crops will not be any more or less sustainable unless herbicide tactics are used judiciously.

Because farmers are the ultimate decision makers for the use and management of GE GR crops, it is important to understand their attitudes and perceptions about the likelihood of selecting for weed resistance to glyphosate. Once farmer attitudes are understood, they need to be coupled with science-based knowledge that guides development of farmer educational programs. These educational programs must increase awareness and knowledge of GR weeds, how to minimize their appearance and how to manage glyphosate resistance when it evolves in weed populations. The educational programs must be robust and provide knowledge that allows farmers to clearly consider other concomitant risks associated with GE GR crops including maintaining long-term sustainability of this technology that will be impacted by their management decisions. A greater educational emphasis on appropriate integrated weed management through the application of best management practices (BMPs) in GE GR crops will help farmers choose diverse weed management tactics that will not lead to a catastrophic loss of chemical weed control tools, while still allowing them to optimize their income from the hectare. The programs must provide a basic background of weed ecology and biology as well as fundamental information about how herbicides work and how herbicide resistance evolves. The programs should be delivered at multiple levels; from internet-based modules to local face-to-face discussions to field demonstrations. It is anticipated that these educational programs will be delivered by the public sector and the life-science companies.

3 A MULTI-STATE, MULTI-YEAR FIELD SCALE STUDY; THE BENCHMARK STUDY

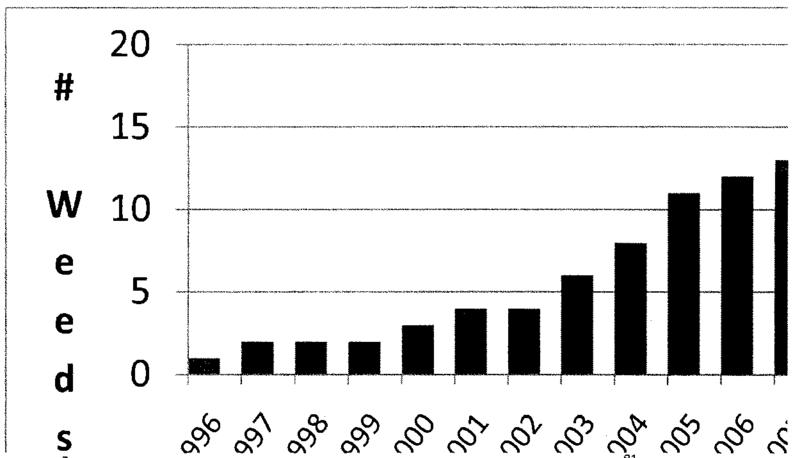
A multi-state field-scale project is underway in the six states where the Benchmark Study Survey was conducted. The objective of the Benchmark Study is to compare GE GR-based crop production system practices with alternative input approaches and determine whether current GE GR crop production systems are sustainable [50]. The Benchmark Study encompasses field-scale assessments of weed management tactics in a variety of crop rotation systems over a number of years. Data from the Benchmark Study will provide an excellent base upon which GE GR crops can be assessed for benefits and risks in an economic sense but also from an ecological impact perspective. In order to address these questions about the sustainability of GE GR technologies, the Benchmark Study has been designed and implemented at the appropriate scale and length of time to allow the monitoring of important elements of the broad-based crop production systems currently employed by US agriculture[25, 40]. While there have been other studies of similar scale [110, 111] and temporal aspect[112], the Benchmark Study is unique by combining both scale and temporal aspects as well as including a diverse range of production areas and crop rotations. This combination of agricultural, temporal, and geographical factors encompassed by the Benchmark Study will result in robust assessments of the sustainability of GE GR-based crop systems.

4 FINAL THOUGHTS

The weed science and agricultural communities must make important considerations when developing glyphosate resistance management strategies. While there has been recent publications describing the mechanisms of resistance to glyphosate in weeds, there is still much to know to insure the sustainability of the GE GR technologies. More research into the specific mechanisms involved is needed before successful scientifically-based management practices can be fully developed and delivered to practitioners in unbiased educational programs. It is also imperative that a more in-depth and broad-based assessment of the societal and ecological benefits and risks of GE crops and specifically, GE GR crops be conducted in order to understand and overcome societal roadblocks hindering the adoption of the GE GR technologies. We have a long journey ahead in achieving economically-sustainable, environmentally-acceptable management of weeds, particularly tactics that will deter the evolution of HR biotypes.

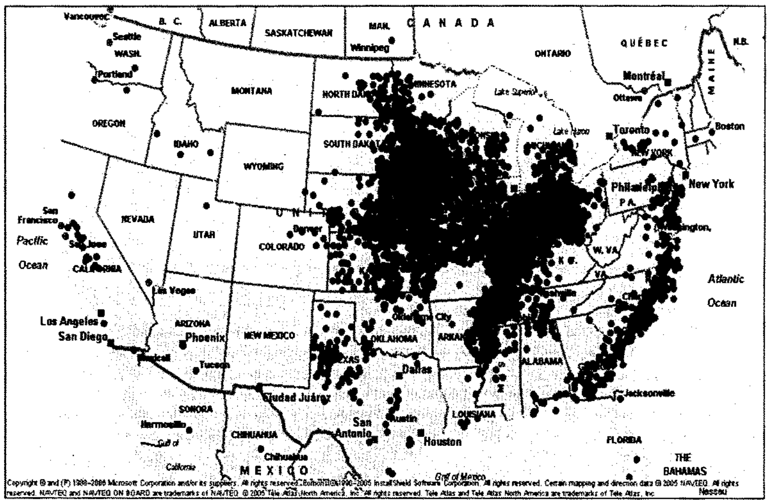
The sustainability of managing glyphosate resistance in weeds is now being tested in millions of hectares of cropland globally, although in a non-scientific, uncontrolled manner. We suggest that the solution to the sustainability of herbicidal weed management in general and specifically, GR weed management in GE GR crops must involve more than finding new herbicides, and developing new herbicide resistant crops. A truly effective and economically and environmentally sustainable strategy will include an integrated systems approach to weed management based on the inclusion of multiple crop improvement and farm management tools that have been developed over the last 60 years, and driven by science-based knowledge. These strategies must be packaged into educational modules that offer reasonable and attractive choices to farmers that result in consistent and effective weed control while reducing selection pressure for herbicide resistance evolution in weeds. The Benchmark Study will provide important information that supports these educational platforms.

Figure 1. Global number of weeds with evolved glyphosate resistance[a]



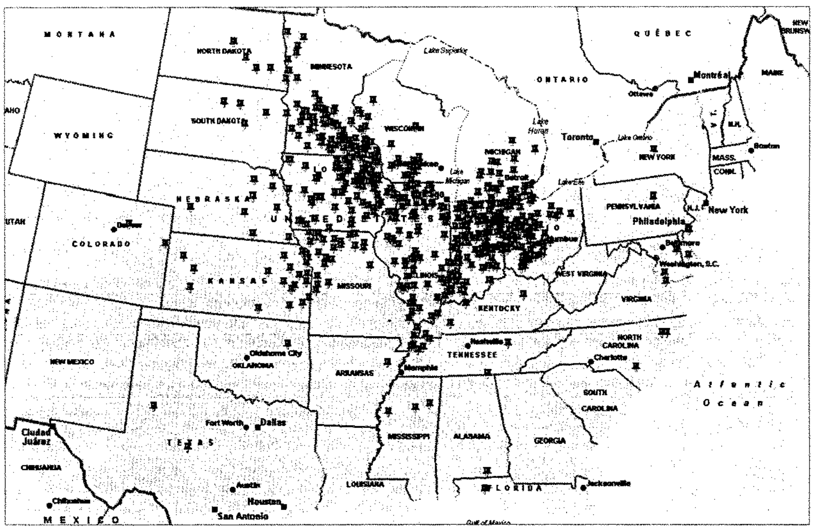
[a]Adapted from International Survey of Herbicide Resistant Weeds [81]

Figure 2. Distribution of putative glyphosate-resistant weeds in 2009[a]



[a]Adapted from and used with permission, USAgriculture Brandfile Survey, Copyright 2010 [90].

Figure 3. Distribution of putative glyphosate-resistant ragweed spp. (*Ambrosia* spp.) in 2009[a]



[a]Adapted from and used with permission, USAgriculture Brandfile Survey, Copyright 2010 [91].

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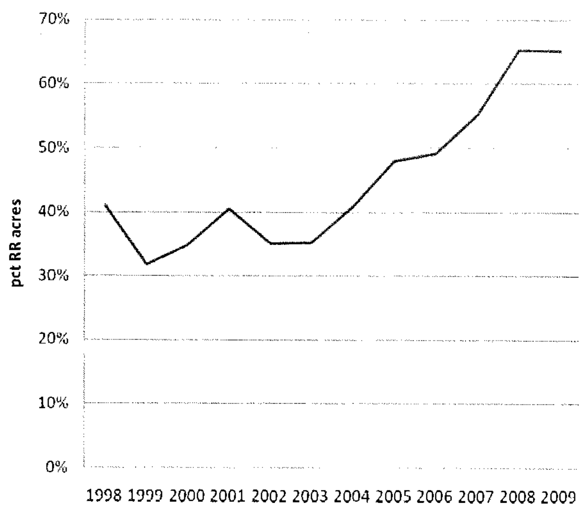
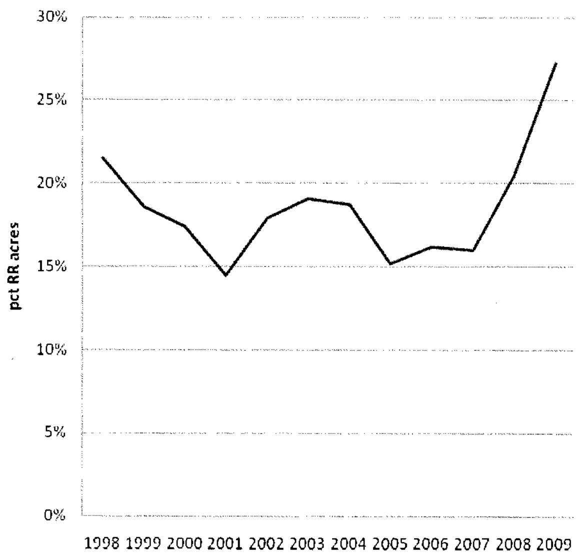
Figure 4. Percent of glyphosate-tolerant corn treated with residual herbicides in the US[a]



[a]Adapted from and used with permission, AgroTrak, 1807 Park 270 Drive Suite 300, St. Louis MO 63146 USA

Figure 5. Percent of glyphosate-tolerant soybean treated with residual herbicides in the US[a]



[a] Adapted from and used with permission, AgroTrak, 1807 Park 270 Drive Suite 300, St. Louis MO 63146 USA

Table 1. Percent of all corn hectares planted to genetically-engineered varieties[a]

State	All GE varieties									
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	Percent of all corn planted									
Illinois	17	16	22	28	33	36	55	74	80	84
Indiana	11	12	13	16	21	26	40	59	78	79
Iowa	30	32	41	45	54	60	64	78	84	86
Kansas	33	38	43	47	54	63	68	82	90	91
Michigan	12	17	22	35	33	40	44	60	72	75
Minnesota	37	36	44	53	63	66	73	86	88	88
Missouri	28	32	34	42	49	55	59	62	70	77
Nebraska	34	34	46	52	60	69	76	79	86	91
North Dakota						75	83	88	89	93
Ohio	9	11	9	9	13	18	26	41	66	67
South Dakota	48	47	66	75	79	83	86	93	95	96
Texas						72	77	79	78	84
Wisconsin	18	18	26	32	38	46	50	64	75	77
Other States	17	20	27	36	46	44	55	67	74	78
U.S.	25	26	34	40	47	52	61	73	80	85

[a]Adapted from Adoption of genetically engineered crop in the U.S. [16]

Table 2. Percent of all upland cotton hectares planted to genetically-engineered varieties[a]

	All GE varieties									
State	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	Percent of upland cotton planted									
Alabama						92	95	95	98	91
Arkansas	70	78	90	95	94	96	94	95	98	97
California	24	40	33	39	52	53	57	61	60	73
Georgia	82	85	93	93	94	95	96	95	97	97
Louisiana	80	91	85	91	93	95	94	96	98	93
Mississippi	78	86	88	92	97	96	98	97	98	93
Missouri						95	97	99	99	98
North Carolina	76	84	86	93	91	95	98	93	95	96
Tennessee						96	93	98	97	97
Texas	46	49	51	53	58	63	70	80	78	81
Other States	74	84	86	88	91	88	90	89	90	90
U.S.	61	69	71	73	76	79	83	87	86	88

[a]Adapted from Adoption of genetically engineered crop in the U.S. [16]

Table 3. Percent of all soybean hectares planted to genetically-engineered varieties[a]

All GE Varieties										
State	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
	Percent of all soybeans planted									
Arkansas	43	60	68	84	92	92	92	92	94	94
Illinois	44	64	71	77	81	81	87	88	87	90
Indiana	63	78	83	88	87	89	92	94	96	94
Iowa	59	73	75	84	89	91	91	94	95	94
Kansas	66	80	83	87	87	90	85	92	95	94
Michigan	50	59	72	73	75	76	81	87	84	83
Minnesota	46	63	71	79	82	83	88	92	91	92
Mississippi	48	63	80	89	93	96	96	96	97	94
Missouri	62	69	72	83	87	89	93	91	92	89
Nebraska	72	76	85	86	92	91	90	96	97	96
North Dakota	22	49	61	74	82	89	90	92	94	94
Ohio	48	64	73	74	76	77	82	87	89	83
South Dakota	68	80	89	84	95	95	93	97	97	98
Wisconsin	51	63	78	84	82	84	85	88	90	85
Other States	54	64	70	76	82	84	86	86	87	87
U.S.	54	68	75	81	85	87	89	91	92	91

[a]Adapted from Adoption of genetically engineered crop in the U.S. [16]

Table 4. Weeds reported to be glyphosate resistant world-wide[a]

Weed Name	Country (# reports)	Resistance Mechanism
1. *Amaranthus palmeri*	USA (9)	Unknown
2. *A. rudis*	USA (5)	Unknown
3. A.tuberculatus	USA (1)	Unknown
4.Ambrosio artemisiifolia	USA (4)	Unknown
S. *Ambrosia trifida*	USA (9)	Unknown
6. *Conyza bonariensis*	South Africa (1)	Unknown
	Spain (1)	Unknown
	Brazil (2)	Unknown
	Israel	Unknown
	Colombia (1)	Unknown
	USA (2)	Unknown
7. *Conyza canadensis*	USA (17)	Known
	Brazil (2)	Unknown
	China (1)	Unknown
	Spain (1)	Unknown
	Czech Republic (1)	Unknown
8. *Conyza sumatrensis*	Spain (1)	Unknown
9. *Digitaria insularis*	Brazil (1)	Unknown
	Paraguay(50)	Unknown
10. *Echinochloa colona*	Australia (1)	Unknown
11.*Eleusine indica*	Malaysia (1)	Known
	Colombia (1)	Unknown
12. *Euphorbia heterophylla*	Brazil (2)	Known
13. *Kachia scoparia*	USA (2)	Unknown
14. *Lolium multiflorum*	Chile (5)	Unknown
	Brazil (1)	Unknown
	USA (2)	Unknown
	Spain (1)	Unknown
	Argentina (1)	Unknown
15. *Lolium rigidum*	Australia (S)	Known
	USA (1)	Known
	South Africa (2)	Unknown
	France (2)	Unknown
	Spain (1)	Unknown
	Italy (1)	Unknown
16. *Parthenium hysterophorus*	Colombia (1)	Unknown
17. *Plantago lanceolata*	South Africa (1)	Unknown
18. *Sorghum halepense*	Argentina (2)	Unknown
	USA (1)	Unknown
19.*Urochloa ponicoides*	Australia (1)	Unknown

[a]Glyphosate-resistant weeds list compiled from the International Survey of Herbicide Resistant[81]

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Superweed Oversight Hearing
Index of Documents Submitted for the Record
August 2010

Filename	Description
GR weeds spreadsheet – May 31 2010.xlxs	Collation of data on glyphosate-resistant weeds from the www.weedscience.com website – gives number of sites & acreage infested and other information
13Years2009 – FullReport.pdf	Report by Dr. Charles Benbrook on the pesticide use impacts of GE crops from 1996 to 2008. Chapters 2 and 4 deal with GR weeds, Chapter 7 with new (multiple) HR crops
Palmer amaranth GR threatens Georgia cotton SEFP 7-6-10	Article by Univ. of Georgia's Brad Haire gives stark picture of how glyphosate-resistant pigweed increases weed control costs from $20/acre to $60-$100/acre and threatens Georgia's cotton industry
Herbicide-Resistant weed collection – early 2010	Collection of farm press articles with facts and figures on increased costs for control of GR weeds, waterhemp in Illinois and Missouri resistant to 4 and 3 families of herbicides, respectively, Micheal Owen's "precipice"quote, etc.
Syngenta sells paraquat to kill GR weeds – 6-8-10	Syngenta (Swiss agrichemical-biotech company) exploits the GR weed epidemic to market its toxic paraquat herbicide (responsible for more pesticide poisonings than any other pesticide)
Dow 2,4-D crops for GR weeds – Bloomberg 5-5-10	Dow exploits GR weed epidemic to advertise for its 2,4-D resistant crops.
EPA HR weed management – Horne 1992	Paper by EPA officer on need for regulation of HR crops to forestall evolution of HR weeds – unfortunately, EPA never took action to do this
EPA-APHIS HR weed resis management.pdf	MoU between APHIS and EPA to collaborate on weed resistance managemenrt programs for HR crops. This agreement was never acted upon
GR weeds 50% species by 2018 Bayer	Bayer officer predicts 50% of agricultural weed species will be GR by the year 2018
Syngenta GR weeds 38 million acres – 2009.pdf	Syngenta's Chuck Foresman predicts (in 2009) that GR weeds will infest 38 million acres by 2013, a four-fold expansion from 2010 levels.
Palmer amaranth GR heavy residue suppress – SEFP 6-22-10	One of many articles touting need for cover crops (an organic method to control weeds and conserve soil) to help suppress GR Palmer amaranth
Glyphosate registration review – FINAL 9-21-09.pdf	CFS comments on EPA's scoping plan for registration review of glyphosate – has charr and data on overall glyphosate use in American agriculture from latest EPA figures, cites studies on Roundup's toxicity to aquatic species and amphibians, and potential toxicity to human health, and adverse impacts of glyphosate on soil microbiota
Herbicide-Resistant crop pipeline – 3-31-10-.doc	Gives partial list of HR crops in the near-term development pipeline of biotech companies
Owen no GR weeds – Monsanto RR soy petition 1993.doc	Letter from Michael Owen stating that cultivation of RR soybeans will not lead to evolution of GR weeds – appended to Monsanto's petition for deregulation for RR soy, 1993

Glyphosate-Resistant Weeds in the U.S.

* Information from reports accessible at: http://www.weedscience.org/Summary/UspeciesMOA.asp?lstMOAID=12&FmHRACGroup=Go, last visited May 18, 2010 for U.S., May 31st, 2010 for Outside U.S. "Year" = year resistant weed population first reported, though a year or more may elapse before the resistance is confirmed, and the report is posted on the website. "Herbicide Mode of Action:" "Glycines" = the herbicide class of which glyphosate is the only member; reports with additional entries in this column indicate weed populations resistant to both glyphosate and one or more herbicides of the cited class of herbicides (e.g. entries with "bipyrilidium" indicate

resistance to paraquat, a member of this class.) Sites Min., Sites Max., Acres Min. & Acres Max. columns give the lower and upperbound estimates of sites/acres infested by the given glyphosate-resistant weed population. Sites on rise? and Acres on rise? convey the opinion of the weed scientist making the report as to whether or not the GR weed population is expanding to occupy more sites and acreage ("Y" = yes, "N" = no, "n.r." = not reported). "Year Last Updated" gives last date the pertinent report was updated, as for changes in acreage infested. For instance, the 2005 report of glyphosate-resistant common waterhemp in Missouri (also resistant to two other classes of herbicides) was quite recently (2010) updated from 1,001 to 10,000 acres infested (as of Nov 2009) to 100,001 to 1,000,000 million acres infested, to reflect its expanded range

Common Name	Species	Year	Herbicide Mode of Action	State	Sites Min.	Sites Max.	Acres Min.	Acres Max.	Sites on rise?	Acres on rise?	Crops infested	Report last updated	Notes
Common Ragweed	Ambrosia artemisiifolia	2004	Glycines	Arkansas	1	1	11	50	n.r.	n.r.	soybeans	2006	
Common Ragweed	Ambrosia artemisiifolia	2007	Glycines	Kansas	1	1	11	50	Y	Y	soybeans	2007	
Common Ragweed	Ambrosia artemisiifolia	2004	Glycines	Missouri	2	5	51	100	n.r.	n.r.	soybeans	2010	
Common Ragweed	Ambrosia artemisiifolia	2006	ALS inhibitors, Glycines	Ohio	1	1	501	1,000	n.r.	n.r.	soybeans	2009	
Tall Waterhemp	Amaranthus tuberculatus (syn. rudis)	2006	ALS inhibitors; Glycines	Illinois	1	1	51	100	n.r.	Y	corn, soybeans	2007	
Tall Waterhemp	Amaranthus tuberculatus (syn. rudis)	2009	Glycines	Iowa	2	5	unknown	unknown	Y	Y	corn, soybeans	2009	
Tall Waterhemp	Amaranthus tuberculatus (syn. rudis)	2006	Glycines	Kansas	2	5	101	500	Y	Y	soybeans	2007	
Tall Waterhemp	Amaranthus tuberculatus (syn. rudis)	2007	Glycines	Minnesota	2	5	51	100	Y	Y	soybeans	2008	

Tall Waterhemp	Amaranthus tuberculatus (syn. rudis)	2010	**Glycines**	Mississippi	2	5	101	500	n.r.	n.r.	soybeans	2010	
Tall Waterhemp	Amaranthus tuberculatus (syn. rudis)	2005	**ALS inhibitors; PPO inhibitors;** Glycines	Missouri	101	500	100,001	1,000,000	Y	Y	corn, soybeans	2010	
Giant Ragweed	Ambrosia trifida	2005	**Glycines**	Arkansas	6	10	101	500	Y	N	soybeans	2008	
Giant Ragweed	Ambrosia trifida	2005	**Glycines**	Indiana	1	1	11	50	Y	Y	soybeans	2007	
Giant Ragweed	Ambrosia trifida	2009	**Glycines**	Iowa	6	10	unknown	unknown	Y	Y	corn, soybeans	2009	
Giant Ragweed	Ambrosia trifida	2006	**Glycines**	Kansas	2	5	501	1,000	Y	Y	soybeans	2007	
Giant Ragweed	Ambrosia trifida	2006	**Glycines**	Minnesota	2	5	101	500	Y	Y	soybeans	2008	
Giant Ragweed	Ambrosia trifida	2009	**Glycines**	Missouri	2	5	101	500	Y	Y	soybeans	2009	
Giant Ragweed	Ambrosia trifida	2004	**Glycines**	Ohio	2	5	101	500	Y	Y	soybeans	2009	
Giant Ragweed	Ambrosia trifida	2006	**ALS inhibitors,** Glycines	Ohio	1	1	101	500	n.r.	n.r.	soybeans	2009	
Giant Ragweed	Ambrosia trifida	2007	**Glycines**	Tennessee	101	500	1,001	10,000	Y	Y	cotton, soybeans	2008	
Hairy Fleabane	Conyza bonariensis	2007	**Glycines**	California	2	5	unknown	unknown	n.r.	n.r.	roadsides	2007	
Hairy Fleabane	Conyza bonariensis	2009	Glycines; bipyrilidiums	California	2	5	unknown	unknown	n.r.	n.r.	roadsides, vineyards	2009	Glyhosate & paraquat
Horseweed	Conyza canadensis	2003	**Glycines**	Arkansas	6	10	1,001	10,000	Y	Y	cotton	2003	
Horseweed	Conyza canadensis	2005	**Glycines**	California	1	1	unknown	unknown	n.r.	n.r.	roadsides	2005	

Horseweed	Conyza canadensis	2000	Glycines	Delaware	101	500	10,001	100,000	n.r.	n.r.	soybeans	2000	
Horseweed	Conyza canadensis	2005	Glycines	Illinois	1,001	10,000	100,001	1,000,000	Y	Y	soybeans	2008	
Horseweed	Conyza canadensis	2002	Glycines	Indiana	2	5	101	500	Y	Y	soybeans	2002	
Horseweed	Conyza canadensis	2005	Glycines	Kansas	51	100	10,001	100,000	Y	Y	cotton, soybeans	2007	
Horseweed	Conyza canadensis	2001	Glycines	Kentucky	2	5	51	100	Y	Y	soybeans	2004	
Horseweed	Conyza canadensis	2002	Glycines	Maryland	6	10	501	1,000	Y	Y	soybeans	2002	
Horseweed	Conyza canadensis	2007	Glycines	Michigan	1	1	51	100	Y	Y	nurseries	2007	
Horseweed	Conyza canadensis	2003	Glycines	Mississippi	101	500	1,001	10,000	Y	Y	corn, cotton, rice, soybeans	2007	
Horseweed	Conyza canadensis	2007	Glycines; bipyrilidiums	Mississippi	1	1	11	50	n.r.	Y	soybeans	2009	Glyhosate & paraquat
Horseweed	Conyza canadensis	2002	Glycines	Missouri	101	500	10,001	100,000	Y	Y	cotton, soybeans	2005	
Horseweed	Conyza canadensis	2002	Glycines	New Jersey	6	10	101	500	Y	Y	soybeans	2002	
Horseweed	Conyza canadensis	2003	Glycines	North Carolina	2	5	6	10	Y	Y	cotton	2003	
Horseweed	Conyza canadensis	2002	Glycines	Ohio	101	500	1,001	10,000	Y	Y	soybeans	2005	
Horseweed	Conyza canadensis	2003	ALS inhibitors; Glycines	Ohio	2	5	101	500	Y	Y	soybeans	2005	
Horseweed	Conyza canadensis	2003	Glycines	Pennsylvania	2	5	101	500	Y	Y	soybeans	2005	
Horseweed	Conyza canadensis	2001	Glycines	Tennessee	501	1,000	2,000,000	5,000,000	Y	Y	cotton, soybeans	2007	

Italian Ryegrass	Lolium multiflorum	2008	Glycines	Arkansas	11	50	1,001	10,000	Y	Y	wheat	2009	
Italian Ryegrass	Lolium multiflorum	2005	Glycines	Mississippi	unknown	unknown	1,001	10,000	Y	Y	cotton, soybeans	2007	
Italian Ryegrass	Lolium multiflorum	2004	Glycines	Oregon	1	1	1	5	N	N	orchards	2005	
Johnsongrass	Sorghum halepense	2007	Glycines	Arkansas	1	1	unknown	unknown	n.r.	n.r.	soybeans	2008	
Kochia	Kochia scoparia	2007	Glycines	Kansas	2	5	51	100	Y	Y	corn, soybeans	2010	First listed 2010
Kochia	Kochia scoparia	2007	Glycines	Kansas	1	1	11	50	n.r.	n.r.	cotton	2010	First listed 2010
Palmer Amaranth	Amaranthus palmeri	2008	Glycines	Alabama	1	1	51	100	Y	Y	soybeans	2009	
Palmer Amaranth	Amaranthus palmeri	2006	Glycines	Arkansas	1001	10,000	100,001	1,000,000	Y	Y	cotton, soybeans	2009	
Palmer Amaranth	Amaranthus palmeri	2005	Glycines	Georgia	101	500	100,001	1,000,000	Y	Y	cotton, soybeans	2008	
Palmer Amaranth	Amaranthus palmeri	2008	Glycines; ALS inhibitors	Mississippi	unknown	unknown	unknown	unknown	n.r.	n.r.	cropland	2009	
Palmer Amaranth	Amaranthus palmeri	2008	Glycines	Missouri	6	10	1001	10000	Y	Y	cotton, soybeans	2010	
Palmer Amaranth	Amaranthus palmeri	2007	Glycines	New Mexico	2	5	51	100	Y	Y	orchards	2009	
Palmer Amaranth	Amaranthus palmeri	2005	Glycines	North Carolina	unknown	unknown	100,001	1,000,000	Y	Y	corn, cotton, soybeans	2008	
Palmer Amaranth	Amaranthus palmeri	2006	Glycines	Tennessee	2	5	101	500	Y	Y	cotton	2007	
Palmer Amaranth	Amaranthus palmeri	2006	Glycines	Tennessee	1001	10,000	100,001	1,000,000	Y	Y	corn, cotton, soybeans	2009	

Rigid Ryegrass	Lolium rigidum	1998	Glycines	California	11	50	1,001	10,000	Y	Y	almonds	2003	
TOTALS					4371	34868	2,641,202	11,390,065					
								Expanding	40	41			
		Horseweed	2,134,031	6,333,260				Not expanding	1	2			
		Palmer	401208	4010700				Not reported	14	12			
		Waterhemp	100,305	1,001,200									

Glyphosate-Resistant Weeds Outside the U.S.

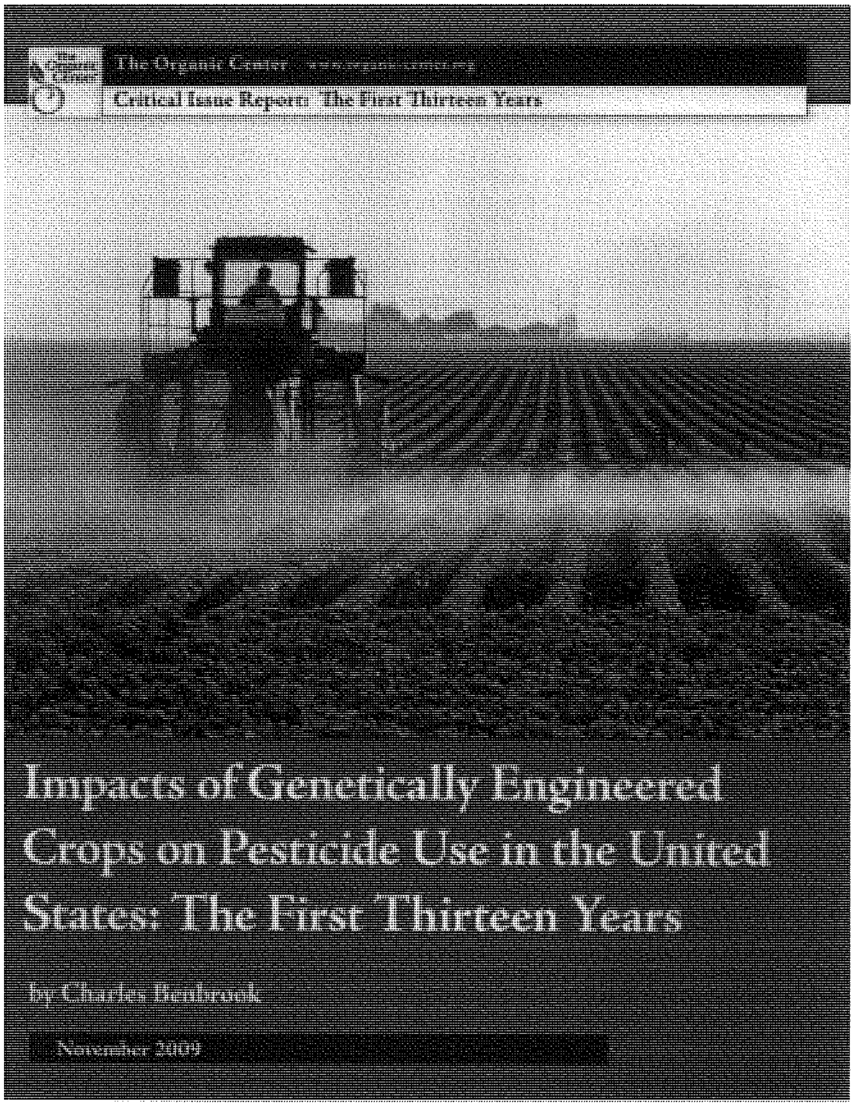
Common Name	Species	Year	Herbicide Mode of Action	Country	Sites Min.	Sites Max.	Acres Min.	Acres Max.	Sites on rise?	Acres on rise?	Crops Infested	Report Last Updated	Notes
Buckhorn Plantain	*Plantago lanceolata*	2003	Glycines	South Africa, Western Cape	2	5	11	50	n.r.	n.r.	orchards, vineyards	2003	
Giant ragweed	*Ambrosia trifida*	2008	Glycines	Canada, Ontario	6	10	51	100	Y	Y	soybeans	2010	Appeared on website 2010
Goosegrass	Eleusine indica	1997	Glycines and ACCase inhibitors	Malaysia	2	5	101	500	n.r.	n.r.	orchards	2002	
Goosegrass	*Eleusine indica*	2006	Glycines	Colombia	2	5	6	10	Y	Y	coffee	2010	
Hairy Fleabane	*Conyza bonariensis*	2003	Glycines	South Africa	2	5	11	50	n.r.	n.r.	orchards, vineyards	2003	
Hairy Fleabane	*Conyza bonariensis*	2004	Glycines	Spain	6	10	1001	10000	Y	Y	orchards	2004	
Hairy Fleabane	*Conyza bonariensis*	2005	Glycines	Brazil	11	50	101	500	Y	Y	corn, fruit, soybean, and wheat	2008	
Hairy Fleabane	*Conyza bonariensis*	2005	Glycines	Brazil	6	10	51	100	Y	Y	fruit, orchards	2006	

Hairy Fleabane	*Conyza bonariensis*	2005	Glycines	Israel	51	100	1001	10000	Y	Y	roadsides	2009
Hairy Fleabane	*Conyza bonariensis*	2005	Glycines	Colombia	2	5	51	100	Y	Y	coffee	2010
Horseweed	*Conyza canadensis*	2005	Glycines	Brazil	11	50	501	1000	Y	Y	fruit, orchards, soybeans	2008
Horseweed	*Conyza canadensis*	2006	Glycines	China	2	5	101	500	Y	Y	orchards	2006
Horseweed	*Conyza canadensis*	2006	Glycines	Spain	2	5	101	500	Y	Y	orchards	2007
Horseweed	*Conyza canadensis*	2007	Glycines	Czech Republic	2	5	unknown	unknown	n.r.	n.r.	railways	2007
Italian Ryeg	*Lolium multiflorum*	2001	Glycines	Chile, VI Region	2	5	101	500	n.r.	n.r.	fruit, orchards	2001
Italian Ryegrass	*Lolium multiflorum*	2002	Glycines	Chile	2	5	unknown	unknown	n.r.	n.r.	orchards	2003
Italian Ryegrass	*Lolium multiflorum*	2002	Glycines; ALS inhibitors	Chile, Región de La Araucania	1	1	11	50	n.r.	n.r.	wheat	2009
Italian Ryegrass	*Lolium multiflorum*	2003	Glycines	Brazil, Rio Grande do Sol	2	5	51	100	Y	Y	orchards, soybeans	2003
Italian Ryegrass	*Lolium multiflorum*	2006	Glycines and ACCase inhibitors	Chile, Región de Los Lagos	1	1	51	100	Y	Y	lupins	2009
Italian Ryegrass	*Lolium multiflorum*	2006	Glycines	Spain, Jaén, Spain	2	5	101	500	Y	Y	orchards	2008
Italian Ryegrass	*Lolium multiflorum*	2007	Glycines	Argentina, Buenos Aires	2	5	51	100	Y	n.r.	cropland	2008

Italian Ryegrass	*Lolium multiflorum*	2007	Glycines; ALS inhibitors; ACCase inhibitors;	Chile, Región de La Araucania	1	1	51	100	Y	Y	barley	2009
Johnsongrass	*Sorghum halepense*	2005	Glycines	Argentina, Province of Salta	11	50	10001	100000	Y	Y	soybeans	2006
Johnsongrass	*Sorghum halepense*	2006	Glycines	Argentina, Province of Santa Fe	2	5	51	100	Y	Y	soybeans	2008
Junglerice	*Echinochloa colona*	2007	Glycines	Australia	2	5	11	50	Y	Y	cropland	2008
Liverseedgrass	*Urochloa panicoides*	2008	Glycines	Australia, New South Wales	2	5	6	10	Y	Y	grain sorghum, and wheat	2008
Perennial ryegrass	*Lolium perenne*	2008	Glyines	Argentina	2	5	11	50	n.r.	n.r.	barley, cropland, soybean, wheat	2010
Ragweed Parthenium	*Parthenium hysterophorus*	2004	Glycines	Colombia	2	5	51	100	Y	Y	fruit	2009
Rigid Ryegrass	*Lolium rigidum*	1996	Glycines	Australia, Victoria	2	5	11	50	n.r.	n.r.	cropland, grain sorghum, and wheat	2000
Rigid Ryegrass	*Lolium rigidum*	1997	Glycines	Australia, New South Wales	11	50	1001	10000	Y	Y	apple, and wheat	2001

Rigid Ryegrass	*Lolium rigidum*	1999	Glycines: ALS inhibitors; ACCase inhibitors; dinitroanilines	Australia, Victoria	1	1	6	10	n.r.	Y	wheat	2008	
Rigid Ryegrass	*Lolium rigidum*	2000	Glycines	Australia, South Australia	11	50	51	100	Y	Y	cereals, and vineyards	2007	
Rigid Ryegrass	*Lolium rigidum*	2001	Glycines	South Africa, Western Cape	11	50	501	1000	Y	Y	cereals, and vineyards	2001	
Rigid Ryegrass	*Lolium rigidum*	2003	Glycines	Australia, Western Australia	1	1	1	5	Y	Y	railways	2008	
Rigid Ryegrass	*Lolium rigidum*	2003	Glycines, ACCase inhibitors, Bipyridiliums	South Africa	1	1	6	10	n.r.	n.r.	vineyards	2005	
Rigid Ryegrass	*Lolium rigidum*	2005	Glycines	France	6	10	501	1000	Y	Y	asparagus, orchards, and vineyards	2007	Two listings for 2005 that appear to be identical
Rigid Ryegrass	*Lolium rigidum*	2006	Glycines	Spain, Valencia	2	5	101	500	Y	Y	orchards	2008	
Rigid Ryegrass	*Lolium rigidum*	2007	Glycines	Italy	2	5	501	1000	Y	Y	orchards, and vineyards	2009	
Sourgrass	*Digitaria insularis*	2006	Glycines	Paraguay	6	10	10001	100000	Y	Y	soybeans	2008	
Sourgrass	*Digitaria insularis*	2008	Glycines	Brazil	1	1	11	50	Y	Y	soybeans	2008	f

Sourgrass	*Digitaria insularis*	2008	Glycines	Paraguay	11	50	501	1000	Y	Y	soybeans	2008	
Sumatran fleabane	*Conyza sumatrensis*	2009	Glycines	Spain	1	1	11	50	Y	Y	orchards	2010	2010
Wild Poinsettia	*Euphorbia heterophylla*	2006	Glycines and ALS inhibitors	Brazil, Rio Grande do Sol	11	50	101	500	Y	Y	soybeans	2007	
			GR Weeds Outside U.S.:		219	663	26941	240445					
			GR Weeds in U.S.:		4371	34868	2641202	11390065					
			GR Weeds Total:		4590	35531	2668143	11630510					


The Organic Center
Critical Issue Report: The First Thirteen Years
Impacts of Genetically Engineered Crops on Pesticide Use in the United States: The First Thirteen Years
by Charles Benbrook
November 2009

PREFACE

This report explores the impact of the adoption of genetically engineered (GE) corn, soybean, and cotton on pesticide use in the United States, drawing principally on data from the United States Department of Agriculture. The most striking finding is that GE crops have been responsible for an increase of 383 million pounds of herbicide use in the U.S. over the first 13 years of commercial use of GE crops (1996-2008).

This dramatic increase in the volume of herbicides applied swamps the decrease in insecticide use attributable to GE corn and cotton, making the overall chemical footprint of today's GE crops decidedly negative. The report identifies, and discusses in detail, the primary cause of the increase -- the emergence of herbicide-resistant weeds.

The steep rise in the pounds of herbicides applied with respect to most GE crop acres is not news to farmers. Weed control is now widely acknowledged as a serious management problem within GE cropping systems. Farmers and weed scientists across the heartland and cotton belt are now struggling to devise affordable and effective strategies to deal with the resistant weeds emerging in the wake of herbicide-tolerant crops.

But skyrocketing herbicide use is news to the public at large, which still harbors the illusion, fed by misleading industry claims and advertising, that biotechnology crops are reducing pesticide use. Such a claim was valid for the first few years of commercial use of GE corn, soybeans, and cotton. But, as this report shows, it is no longer.

An accurate assessment of the performance of GE crops on pesticide use is important for reasons other than correcting the excesses of industry advertising. It is also about the future direction of agriculture, research, and regulatory policy.

Herbicides and insecticides are potent environmental toxins. Where GE crops cannot deliver meaningful reductions in reliance on pesticides, policy makers need to look elsewhere. In addition to toxic pollution, agriculture faces the twin challenges of climate change and burgeoning world populations. The biotechnology industry's current advertising campaigns promise to solve those problems, just as the industry once promised to reduce the chemical footprint of agriculture. Before we embrace GE crops as solution to these new challenges, we need a sober, data-driven appraisal of its track record on earlier pledges.

The government has the capability, and we would argue a responsibility, to conduct periodic surveys of sufficient depth to track and accurately quantify the impacts of GE crops on major performance parameters, including pesticide use. While the USDA continued to collect farm-level data on pesticide applications during most of the 13 years covered in this report, the Department has been essentially silent on the impacts of GE crops on pesticide use for almost a decade. This is why the groups listed in the Acknowledgements commissioned this study by Dr. Benbrook, the third he has done on this topic since 2002.

We hope that this report will help trigger new government and academic assessments of the performance, costs, and risks associated with today's GE crops. Without such assessments, American agriculture is likely to continue down the road preferred by the biotechnology industry, a path that promises to maximize their profits by capturing a larger share of farm income, and limit the ability of plant breeders and other agricultural scientists to address other pressing goals of wider importance to society as a whole.

Dr. Margaret Mellon
Director, Food and Environment Program
Union of Concerned Scientists

Mr. Mark Retzloff
Board Chair, The Organic Center
President, Aurora Organic Dairy

ACKNOWLEDGMENTS

This is the third report we have done on the impact of genetically engineered (GE) crops on overall pesticide use in the United States. The first was released as Ag BioTech InfoNet Technical Paper Number 6 in 2003 and covered the first eight years of commercial use of GE seeds. The second report was completed in October, 2004 and analyzed the first nine years of commercial use.[1]

Several people have contributed to this report, as well as to the development and refinement of the model used in all three reports. Thanks to all of them for sharing their expertise and knowledge.

Karen Benbrook compiled and manages the Access database encompassing USDA pesticide use data going back to 1964. This valuable research tool makes it possible to carry out analytical projects drawing on annual USDA pesticide use surveys. Karen also developed the graphics and desk-top published the report.

Karie Knoke, K-Comp Solutions, has contributed to the development and refinement of the Microsoft Excel-based analytical model.

Over the years Dr. Michael Hansen of the Consumers Union, and Dr. Robert Kremer, with the Agricultural Research Service in Columbia, Missouri have provided key information for developing and applying the projection model. Also, thanks to William Freese, Center for Food Safety, for assistance in compiling information on resistant weeds, emerging GE crops, and current developments in the biotechnology industry and regulatory agencies. Bill's attention to detail and depth of knowledge were invaluable as the project unfolded.

The analytical work required to complete this report was funded by a coalition of non-governmental organizations including the Union of Concerned Scientists, the Center for Food Safety, the Cornerstone Campaign, GE Policy Project, Greenpeace, and Rural Advancement Foundation International - USA. The Organic Center supported the writing and publication of the report.

I am grateful for the encouragement, counsel, and technical support of Dr. Margaret (Mardi) Mellon and Dr. Jane Rissler of the Union of Concerned Scientists for my work over the last decade on the impact of GE crops on pesticide use.

I am solely responsible for the analytical approach and model, decisions required to deal with data gaps, the interpretation and communication of findings, and any errors or lapses in judgment.

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1 Access the October, 2004 report, Ag BioTech InfoNet Technical Paper Number 7, at http://www.organic-center.org/science.latest.php?action=view&report_id=158

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ABBREVIATIONS

AI – Active Ingredient
ALS – Acetolactate synthase, a major herbicide family of chemistry
ARMS - Agricultural Resources Management Survey
AMS - Agricultural Marketing Service
BXN - Bromoxynil Tolerant
Bt – Bacillus Thuriengensis
CWR – Corn Rootworm
ECB – European Corn Borer
EPA - Environmental Protection Agency
ERS – Economic Research Service
GE – Genetically Engineered
GM - Genetically Modified
GR – Glyphosate-Resistant
HT – Herbicide-Tolerant
IPM - Integrated Pest Management
LL – Liberty Link
NAS - National Academy of Sciences
NASS - National Agricultural Statistics Service
NCFAP - National Center for Food and Agriculture Policy
NOP - National Organic Program
PPO - Protoporphyrinogen Oxidase, an enzyme
RR – Roundup Ready
SWCB – Southwestern Corn Borer
USDA – United States Department of Agriculture
WCB – Western Corn Borer

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1. Executive Summary

In a recent story tracking the emergence of weeds resistant to glyphosate (Roundup) herbicides, a North Carolina farmer said that "Roundup is the greatest thing in agriculture in my lifetime."

A retired weed scientist admits in the same story "In hindsight, we screwed up. We can't rely on the same thing over and over."

But farmers did, turning glyphosate herbicide and genetically engineered (GE) corn, soybeans, and cotton into the most stunning and profitable market success story in the history of the pesticide and seed industry.

This report documents some of the key impacts of GE crops on their way to market dominance and explains why the total pounds of herbicides applied on GE crops has spiked so sharply in recent years, with more increases to come.

But first, some key terms are defined.

A "pesticide" is a chemical that controls pests. The term encompasses herbicides applied to control weeds, insecticides used to manage insects, and fungicides sprayed to manage plant diseases.

A pesticide "active ingredient" (AI) is the chemical (or chemicals) in a pesticide that is responsible for killing or otherwise controlling target pests.

"Pesticide use" is usually measured as pounds of pesticide "active ingredient" applied per acre, or on a given crop over some period of time.

A "trait" in a genetically engineered crop is the unique characteristic or attribute added to the genetic makeup of the crop using recombinant DNA (gene-splicing) technology. The capacity of a plant to withstand applications of a particular herbicide is an example of a GE crop trait.

"Stacked" GE seeds are those expressing two or more distinct traits.

"Trait acres" are the number of GE crop acres that contain a particular trait. One acre planted to a single-trait GE crop represents one trait acre, an acre planted to a "stacked" crop with two traits is equivalent to two trait acres, and so on. (This is why GE "trait acres" planted exceeds total GE crop acres planted).

GE seeds were introduced commercially in 1996 and now dominate the production of corn, soybeans, and cotton in the United States. GE crops contain one or both of two major categories of traits:

- Herbicide-tolerant (HT) crops are genetically engineered to survive direct application of one or more herbicides during the growing season, chemicals that would otherwise kill or severely stunt the crop. The major HT crops are soybeans, corn, and cotton. Nearly all HT trait acres are planted to "Roundup Ready" (RR) seeds that tolerate applications of Monsanto's glyphosate (Roundup) herbicide, the active ingredient in Roundup berbicide.
- *Bt* crops are engineered to produce toxins derived from the natural bacterium *Bacillus thuringiensis* (*Bt*) in plant cells. These toxins are lethal to certain agricultural insect pests.

A. This Report

This report focuses on the impacts of GE crops on pesticide use, as measured by the total pounds applied on HT and *Bt* corn in contrast to conventional corn, HT soybeans in contrast to conventional soybeans, and HT and *Bt* cotton compared to conventional cotton.

Official U. S. Department of Agriculture (USDA) surveys are the source of most of the data used in this report on the acres planted to each GE trait in corn, soybeans, and cotton. Annual "trait acreage" reports from Monsanto provide more nuanced data on the acres planted to crops with specific traits and trait combinations.

The data in this report on the acres planted to crops with each major GE trait are of high quality and are not controversial.

Pesticide use data come from annual surveys done by the USDA's National Agricultural Statistics Service (NASS). These surveys encompass the percentage of crop acres treated with each pesticide active ingredient, average rates of application, the number of applications, and pounds of active ingredient applied.

NASS pesticide use data are also of high quality and have stood the test of time, but NASS surveys do not report pesticide use separately on crop acres planted to GE seeds, in contrast to acres planted to conventional seeds. Hence, a method was developed for each GE crop and trait to estimate from NASS data how much more or less pesticide was used on a GE acre versus an acre planted with conventional seeds (for more methodological details, see Chapters 2, 4, and 5).

These differences in pesticide use per acre are calculated by crop, trait, and year. The result is then multiplied by the acres planted to each GE crop trait in a given year. Last, the model adds together the differences in the total pounds of pesticides applied across all crops, traits and years, producing this report's bottom line. It's a big number -- an additional 318 million pounds of pesticides were applied due to the planting of GE crops from 1996 through crop year 2008.

B. Key Findings

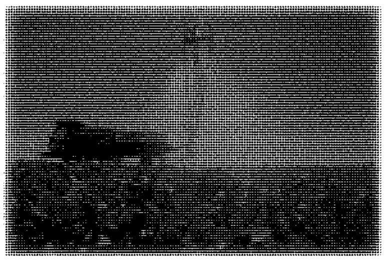
Farmers planted 941 million acres of GE HT corn, soybeans, and cotton from 1996 through 2008. HT soybeans accounted for two-thirds of these acres.

Bt corn and cotton were grown on 357 million acres, with corn accounting for 79% of these acres.

Thus, about 1.3 billion trait acres of HT and *Bt* crops have been grown between 1996 and 2008. HT crops account for 72% of total GE crop trait acreage. The actual number of acres planted to GE soybeans, corn, and cotton over this period is considerably less than 1.3 billion due to the prevalence of "stacked" versions of GE corn and cotton.

Impacts on Pesticide Use

GE crops have increased overall pesticide use by 318.4 million pounds over the first 13 years of commercial use, compared to the amount of pesticide likely to have been applied in the absence of HT and *Bt* seeds.



The 318.4 million pound increase represents, on average, an additional 0.25 pound of pesticide active ingredient for every GE trait acre planted over the first 13 years of commercial use.

Bt corn and cotton have delivered consistent reductions in insecticide use totaling 64.2 million pounds over the 13 years. *Bt* corn reduced insecticide use by 32.6 million pounds, or by about 0.1 pound per acre. *Bt* cotton reduced insecticide use by 31.6 million pounds, or about 0.4 pounds per acre planted.

HT crops have increased herbicide use by a total of 382.6 million pounds over 13 years. HT soybeans increased herbicide use by 351 pounds (about 0.55 pound per acre), accounting for 92% of the total increase in herbicide use across the three HT crops.

Recently herbicide use on GE acres has veered sharply upward. Crop years 2007 and 2008 accounted for 46% of the increase in herbicide use over 13 years across the three HT crops. Herbicide use on HT crops rose a remarkable 31.4% from 2007 to 2008.

GE crops reduced overall pesticide use in the first three years of commercial introduction (1996-1998) by 1.2%, 2.3%, and 2.3% per year, but increased pesticide use by 20% in 2007 and by 27% in 2008.

Two major factors are driving the trend toward larger margins of difference in the pounds of herbicides used to control weeds on an acre planted to HT seeds, in comparison to conventional seeds:

- The emergence and rapid spread of weeds resistant to glyphosate, and
- Incremental reductions in the average application rate of herbicides applied on non-GE crop acres.

Resistant Weeds

The widespread adoption of glyphosate-resistant (GR), RR soybeans, corn, and cotton has vastly increased the use of glyphosate herbicide. Excessive reliance on glyphosate has spawned a growing epidemic of glyphosate- resistant weeds, just as overuse of antibiotics can trigger the proliferation of antibiotic-resistant bacteria.

GR weeds were practically unknown before the introduction of RR crops in 1996. Today, nine or more GR weeds collectively infest millions of acres of U.S. cropland. Thousands of fields harbor two or more resistant weeds. The South is most heavily impacted, though resistant weeds are rapidly emerging in the Midwest, and as far north as Minnesota, Wisconsin, and Michigan. In general, farmers can respond to resistant weeds on acres planted to HT crops in five ways:

- Applying additional herbicide active ingredients,
- Increasing herbicide application rates,
- Making multiple applications of herbicides previously sprayed only once,
- Through greater reliance on tillage for weed control, and
- By manual weeding.

In the period covered by this report, the first three of the above five responses have been by far the most common, and each increases the pounds of herbicides applied on HT crop acres.

GR pigweed (Palmer amaranth) has spread dramatically across the South since the first resistant populations were confirmed in 2005, and already poses a major threat to U.S. cotton production. Some infestations are so severe that cotton farmers have been forced to abandon cropland, or resort to the preindusrrial practice of "chopping cotton" (hoeing weeds by hand).

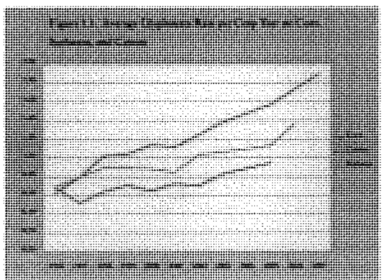
Resistant horseweed (marestail) is the most widely spread and extensive glyphosate-resistant weed. It emerged first in Delaware in the year 2000, and now infests several million acres in at least 16 states of the South and Midwest, notably Illinois. GR horseweed, giant ragweed, common waterhemp, and six other weeds are not only driving substantial increases in the use of glyphosate, but also the increased use of more toxic herbicides, including paraquat and 2,4-D, one component of the Vietnam War defoliant, Agent Orange.

Growing reliance on older, higher-risk herbicides for management of resistant weeds on HT crop acres is now inevitable in the foreseeable future and will markedly deepen the environmental and public health footprint of weed management on over 100 million acres of U.S. cropland. This footprint will both deepen and grow more diverse, encompassing heightened risk of birth defects and other reproductive problems, more severe impacts on aquatic ecosystems, and much more frequent instances of herbicide-driven damage to nearby crops and plants, as a result of the off-target movement of herbicides.

Figure 1.1 shows the upward trend in the pounds of glyphosate applied per crop year[1] across the three HT crops. USDA NASS data show that since 1996, the glyphosate rate of application per

[1] NASS defines the pesticide "rate per crop year" as the average one-time rate of application multiplied by the average number of applications.

crop year has tripled on cotton farms, doubled in the case of soybeans, and risen 39% on corn. The average ***annual increase*** in the pounds of glyphosate applied to cotton, soybeans, and corn has been 18.2%, 9.8%, and 4.3%, respectively, since HT crops were introduced.



Lower-Dose Herbicides Used with Conventional Crops

The second key factor responsible for the increasing margin of difference in herbicide use on HT versus conventional crops is progress made by the pesticide industry in discovering more potent active ingredients that are effective at progressively lower average rates of application. As a result of these discoveries, the average per acre amount of herbicides applied to conventional crops has steadily fallen since 1996. In contrast, glyphosate/Roundup is a relatively high-dose herbicide and glyphosate use rates have been rising rapidly on HT crop acres, as clearly evident in the NASS data presented above.

The average rate of herbicides applied to conventional soybean acres dropped from 1.19 pounds of active ingredient per acre in 1996 to 0.49 pounds in 2008. The steady reduction in the rate of application of conventional soybean herbicides accounts for roughly one-half of the difference in herbicide use on GE versus conventional soybean acres. The increase in the total pounds of herbicides applied to HT soybean acres, from 0.89 pounds in 1996 to 1.65 pounds in 2008, accounts for the other one-half of the difference.

A similar trend is evident with insecticides. Corn insecticides targeting the corn rootworm (CRW) were applied at around 0.7 pound per acre in the mid-1990s and about 0.2 pound a decade later. The exception to this rule of dramatically falling pesticide use rates has been cotton insecticides targeting the budworm/bollworm complex. The rate of these products has fallen marginally from 0.56 to 0.47 pounds per acre.

C. The Road Ahead for GE Corn, Soybeans, and Cotton

The vast majority of corn, soybean, and cotton fields in the U.S. in 2010 will be sown with GE seeds. This is not a bold prediction because the non-GE seed supply is so thin now that most farmers will be purchasing GE seeds for the next several years, whether they want to or not.

The GE corn, soybean, and cotton seeds planted over the next five to 10 years will, if current trends hold, contain increasing numbers of stacked traits (usually three or more), cost considerably more per acre, and pose unique resistance management, crop health, food safety, and environmental risks. HT crops will continue to drive herbicide use up sharply, and those increases in the years ahead will continue to dwarf the reductions in insecticide use on *Bt* crop acres.

Tipping Point for RR Crops

Crop year 2009 will probably mark several tipping points for RR crops. The acres planted to HT soybeans fell 1% from the year before, and will likely fall by a few additional percentage points in 2010. Farmer demand for conventional soybeans is outstripping supply in several states, and universities and regional seed companies are working together to close the gap.

Reasons given by farmers for turning away from the RR system include the cost and challenges inherent in dealing with GR weeds, the sharply increasing price of RR seeds, premium prices offered for non-GE soybeans, the poorer than expected and promised yield performance of RR 2 soybeans in 2009, and the ability of farmers to save and replant conventional seeds (a traditional practice made illegal with the purchase of HT/RR seeds).

In regions where farmers are combating resistant weeds, especially Palmer amaranth and horseweed in the South, university experts are projecting increases of up to $80 per acre in costs associated with HT crops in 2010. This increase represents a remarkable 28% of soybean income per acre over operating costs, based on USDA's bullish forecast for 2010 soybean income (average yield 42 bushels; average price, about $9.90).

The economic picture dramatically darkens for farmers combating resistant weeds under average soybean yields (36 bushels) and market prices ($6.50 per bushel). Such average conditions would generate about $234 in gross income per acre. The estimated $80 increase in 2010 costs per acre of HT soybeans would then account for one-third of gross income per acre, and total cash operating costs would exceed $200 per acre, leaving just $34 to cover land, labor, management, debt, and all other fixed costs. Such a scenario leaves little or no room for profit at the farm level.

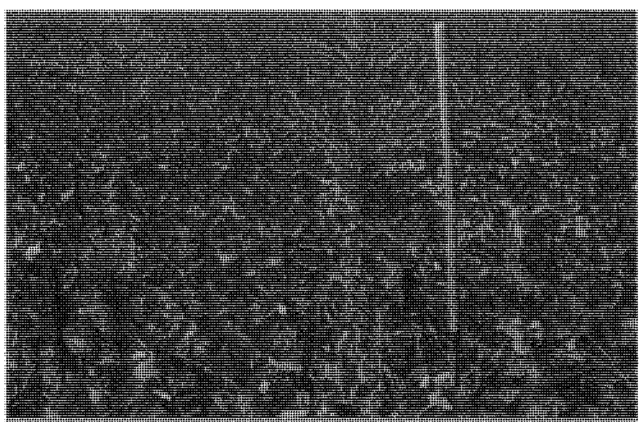
Resistance Management Still Key in Sustaining *Bt* Crop Efficacy

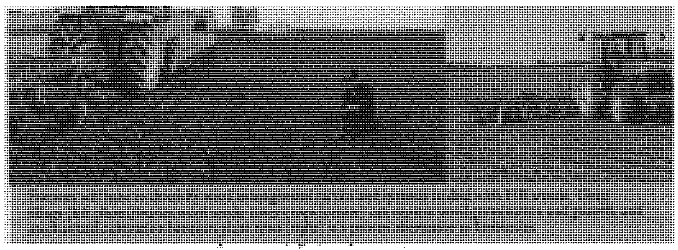
The future of *Bt* transgenic crops is brighter, but if and only if resistance is prevented. The seed industry, the Environmental Protection Agency (EPA), and university scientists have collaborated effectively in the last 13 years in an effort to closely monitor and prevent resistance to *Bt* crops.

But now, some experts argue that the emphasis on resistance management in *Bt* crops can be relaxed. They point out that the trend in the seed industry toward stacking multiple *Bt* toxins in corn and cotton varieties should reduce the risk of resistance. The EPA has apparently been persuaded by this argument, since it has approved several recent *Bt* crops with substantially relaxed resistance management provisions.

History suggests that lessened diligence in preventing *Bt* resistance is premature. It took 10-15 years for corn and cotton insects to develop resistance to each new type of insecticide applied to control them since the 1950s.

Bt cotton has now been grown for 14 years, but the acreage planted to it did not reach one-third of national cotton acres until 2000. Plus, the first populations of *Bt* resistant bollworms were discovered in Mississippi and Arkansas





cotton fields in 2003, about when experts predicted field resistance would emerge.

Bt corn for CRW control has been planted on significant acreage for only three years (2007-2009). *Bt* corn hybrids for Eastern corn borer (ECB) control are still planted on just a little over one-half national corn acres. For both types of *Bt* corn, and especially in the case of *Bt* corn for CRW control, it is far too early to declare with confidence that resistance is no longer a significant threat.

Future Trends

Agricultural biotechnology firms have thus far devoted the lion's share of their R&D resources to the development of only two biotech traits: herbicide tolerance and insect resistance. Pest control systems largely based on these traits are in jeopardy, biologically and economically, for the simple reason that they foster near-exclusive reliance on single pest control agents – season-long, year after year, and over vast areas of cropland. These are "perfect storm" conditions for the evolution and spread of resistance.

There is no serious dispute that RR crops have been popular, for the most part effective, and about budget-neutral for farmers. But they have fostered unprecedented reliance on glyphosate for weed control, and overreliance has spawned a growing epidemic of glyphosate-tolerant and resistant weeds.

Two major players in the industry – Monsanto and Syngenta – are now offering to pay farmers rebates on the order of $12 per acre to spray herbicides that work through a mode of action different from glyphosate. Monsanto's program will even pay farmers to purchase herbicides sold by competitors, a sign of how seriously Monsanto now views the threat posed by resistance to its bread and butter product lines.

While corn, soybean, and cotton farmers view the spread of resistant weeds as a slow moving train wreck eroding their bottom line, the seed and pesticide industry sees new market opportunities and profit potential arising in the wake of resistant weeds. A large portion of industry R&D investments are going into the development of crops that will either withstand higher rates of glyphosate applications, or tolerate applications of additional herbicides, or both. In short, the industry's response is more of the same.

One major biotech company has applied for and received a patent covering HT crops that can be directly sprayed with herbicide products falling within seven or more different herbicide families of chemistry.[2] These next-generation HT crops will likely be sprayed with two or three times the number of herbicides typically applied today on fields planted with HT seeds, and the total pounds of herbicides applied on HT crops, and the cost of herbicides, will keep rising as a result.

Addressing the rapidly emerging problem of resistant weeds in this way makes as much sense as pouring gasoline on a fire in the hope of snuffing out the flames. Despite these ill-conceived efforts, unmanageable weeds with their roots in the Southeast will almost certainly continue to spread north and west, first into the fringes but eventually throughout the Corn belt.

2 Herbicides within a "family of chemistry" work through the same mode of action.

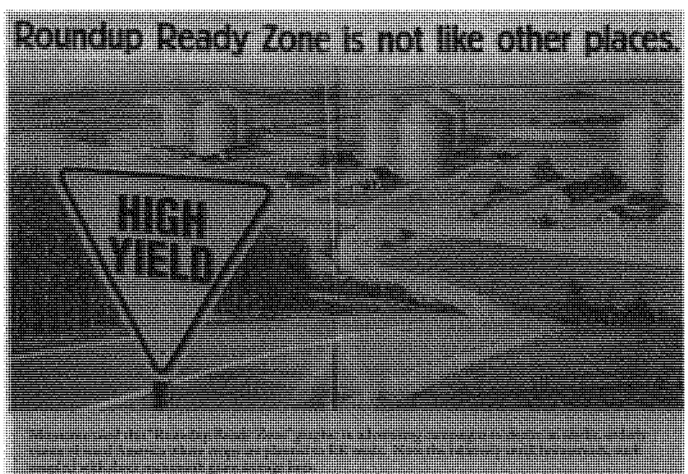
Major weed management problems in the cotton industry in the Southeastern U.S. will not have a dramatic impact on U.S. agriculture or national well being, but what if the same fate lies ahead for corn and soybean producers? It well might in the absence of major changes in weed management systems and regulatory policies.

Instead of just spraying more, farmers must diversify the tactics embedded in their weed management systems, alter crop rotations, scrupulously follow recommended herbicide resistance management plans, and utilize tillage more aggressively to bury herbicide-tolerant weed seeds deep enough to keep them from germinating.

Sustaining the efficacy of *Bt* crops is both important and possible. The emergence in 2003 of the first, isolated field populations of a major cotton insect resistant to *Bt* is troubling, but also reinforces the importance of today's resistance management plans, which have kept the resistant populations found in Mississippi and Arkansas from spreading. The industry has recently proposed, and EPA has approved, backing away from *Bt* resistance management practices, steps that recklessly place the future efficacy of *Bt* crops and *Bt* insecticide sprays at risk.

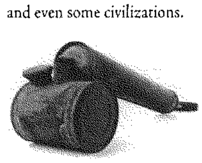
Overall pesticide use is bound to continue rising on GE corn, soybeans, and cotton. Even if the new, multiple-toxin versions of *Bt* corn and cotton prove more effective in reducing insect pressure and feeding damage, the reduction in pounds of insecticides achieved as a result will be dwarfed by the continuing surge in herbicide use on HT crops.

The immediate and pressing goals for farmers, scientists and the seed industry include developing weed management systems capable of getting ahead of resistant weeds, assuring no lapse in the commitment to preserving the efficacy of *Bt* toxins, and expanding the supply and quality of conventional corn, soybean, and cotton seeds. The last goal will likely emerge as the most vital, since the productivity of our agricultural system and the quality of much of our food supply begins with and depends on seeds.



2. Introduction, Data Sources, and Methodology

Weeds, insects, and plant diseases can significantly reduce the yield and quality of crops. Since the dawn of agriculture and around the world, managing pests has been a constant, annual, and unavoidable challenge for farmers. The effectiveness of steps taken to keep pest losses to a minimum has often meant the difference between life and death for families, tribes, communities, and even some civilizations.



Since World War II, pesticides have become the major tool employed by U.S. farmers to combat weed competition and insect damage. The term "pesticide" encompasses any chemical designed to control, manage, or kill a pest. There are three major types of pesticides: herbicides to control weeds, insecticides to manage insects, and fungicides to control plant disease. There are several other types of pesticides including rodenticides, nematicides (nematodes), antibiotics (bacteria), plant growth regulators, and miticides (mites).

All pesticides contain one or more "active ingredients" (AI). These are the chemicals within pesticide products that are responsible for either killing a target pest outright, or undermining the ability of a target pest to thrive or do damage to a growing crop. "Inert ingredients" are added to pesticide products to improve the efficacy and stability of a pesticide.

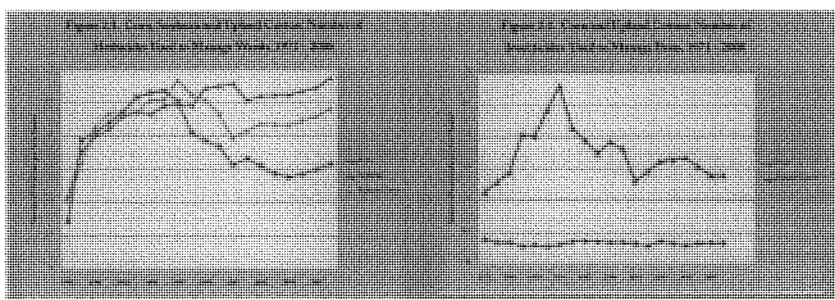
Pesticides work through many different modes of action. Some modes of action disrupt one or more essential physiological processes within the target pest sufficiently to kill the pest in a short period of time. Other modes of action involve blocking how a pest is able to digest food, impeding growth, or impairing reproduction.

Natural biochemicals like insect pheromones (scents that attract insects), botanicals, bacteria like *Bacillus thuriengensis* (*Bt*), and horticultural oils are also classified by the Environmental Protection Agency (EPA) as "pesticides" because of their ability to help manage pests. Most of these work through a non-toxic mode of action and many are approved by the United States Department of Agriculture's (USDA's) National Organic Program (NOP) for use on certified organic farms.

A. Tracking Pesticide Use and Risk

There are two basic ways to track changes in reliance on pesticides: first, the number of different pesticides applied on a given acre, and second, the total pounds of pesticide active ingredient applied per acre in a given year.

Pesticide use surveys carried out by the USDA (see section below on data sources for details) show that corn fields in the U.S. were treated with an average 1.07 herbicides and 0.39 insecticides in 1971, while in that year 0.72 herbicides were used on soybeans, as shown in Figure 2.1.



Two decades later in 1991, corn farmers applied on average about two different herbicides per acre. Since 1991 reliance has gradually increased and reached a peak of 2.78 herbicides applied to the average acre in 2001.

Corn growers have been less reliant on insecticides than on herbicides, as clear in Figures 2.1 and 2.2. Between 29% and 39% of national corn acres have been treated with an insecticide since 1971. This lessened reliance compared to herbicides reflects two facts on the ground:

- Weeds are a problem every year in every field, while corn insects are episodic pests that cause problems serious enough to warrant treatments in only some regions and in some years; and

- Planting corn and soybeans in a crop rotation is typically very effective in suppressing most important corn insect pests.

Increasing reliance by soybean farmers over time on a greater number of herbicides is evident in Figure 2.1, until the introduction of Roundup Ready (RR) glyphosate-resistant soybeans in 1996. The number of herbicides applied per acre fell from 2.7 in 1996 to 1.38 in 2005, although the number of herbicides applied on soybean acres is now rising as a result of the emergence of weeds resistant to glyphosate. Very few soybean acres are treated with insecticides.

In terms of the volume, or pounds of pesticide active ingredient applied per acre, there were about three pounds of insecticides applied in 1964 for each pound of herbicide on major U.S. field, fruit and vegetable crops.[1] Just seven years later in 1971, 176 million pounds of herbicides were applied, in contrast to 128 million pounds of insecticides.

Since 1971, the shift to much lower-dose insecticides has reduced the total pounds of insecticides applied to under 40 million in 2004. Herbicide use, on the other hand, rose from 176 million pounds in 1971 to 363 million pounds in 1997, despite the registration of several lower-dose herbicides starting in the early 1980s.

In 2004 across major field crops, the ERS reports that 7.6 pounds of herbicides were applied for each pound of insecticide. **The unmistakable dominance of herbicides in measures of the total pounds of pesticides applied is why the performance of herbicide-tolerant GE crops determines, for the most part, the impact of GE technology on overall pesticide use.**

Table 2.1 provides an overview of the acres planted and pesticide use from 1996 through 2008 for the three major GE crops: corn, soybeans, and cotton. Across these three crops and the 13 years covered in this analysis, 3.8 billion pounds of herbicides were applied, compared to 409 million pounds of insecticides – **9.3 pounds of herbicides for each pound of insecticide.** Cotton is clearly an exception in that insecticide use accounts for 43% of the total pounds of pesticides applied to that crop.

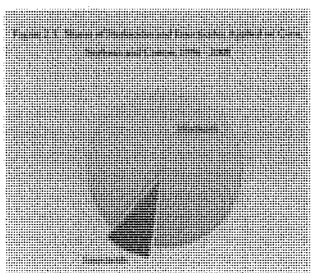
Environmental and public health problems with pesticides began to attract the attention of both scientists and citizens in the 1960s. Rachel Carson's famous 1962 book *Silent Spring* deepened public

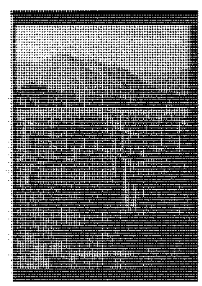
[1] "*Agricultural Resources and Environmental Indicators, 2006 Edition*," edited by Wiebe, K., and Gollehon, N., Economic Research Service (ERS) Information Bulletin Number 16, USDA, July 2006.

Table 2.1. Corn, Soybean, and Cotton Acreage Planted, Average Pesticide Use per Acre, and Total Pounds Applied: 1996 - 2008 (see notes)

	Corn	Soybean	Upland Cotton	Total Three Crops
Total Acres Planted	1,050,999,000	938,854,000	173,695,300	2,164,648,300
Herbicide Pounds Applied	[illegible]	[illegible]	[illegible]	[illegible]
Insecticide Pounds Applied	136,787,180	14,199,001	258,949,730	406,535,910
Total Pounds Applied (Herbicides and Insecticides)	[illegible]	[illegible]	[illegible]	[illegible]
Average Pesticide Use per Acre (Pounds)	2.35	1.23	3.55	1.96
Herbicides as Percent of Total	95%	99%	59%	90%
Insecticides as Percent of Total	5%	1%	41%	10%

Notes: [illegible]





awareness and concern over the impact of persistent, chlorinated hydrocarbon insecticides. Government scientists and regulatory agencies focused more attention on pesticide use and risks, both confirming the existence of significant environmental impacts from pesticide use, especially insecticides, and gaining insight into how pesticides were harming birds and other wildlife, as well as people.

As pesticide use grew in the 1970s and 1980s, so did evidence of adverse impacts on exposed wildlife populations and people. The regulation of pesticide use and risks became one of the dominant areas of focus for the EPA and the environmental community in the 1980s and through much of the 1990s. An overview of pest management, pesticide use and risks, and efforts to move toward more prevention-oriented pest management systems is provided in the 1996 Consumers Union book *Pest Management at the Crossroads* (PMAC).[2]

A key theme of PMAC is that changes in crop rotations and other farming practices can sharply reduce pest pressure and reliance on pesticides.

B. Milestones and Major Impacts of GE Crops

The application of recombinant DNA technology in crop breeding, popularly known as genetic engineering, has been promoted by the biotechnology industry as another means to reduce pesticide use. Genetically engingeered (GE) crops were introduced commercially in the U.S. in 1996 and were rapidly adopted by corn, soybean, and cotton farmers.

By 1998, concern and controversy over the health and environmental impacts of GE plants had, for the most part, overshadowed long-

2 Benbrook, C., Groth, E., Halloran, J., Hansen, M., Marquardt, S., (1996). *Pest Management at the Crossroads* (PMAC), Consumers Union. PMAC also discusses the likely impacts and problems associated with GE crops, based on what was then known about the technologies.

Table 2.2. Percent of National Acres Planted to Herbicide-Tolerant (HT) and *Bt* Crop Varieties [Combines acres planted to single- and multiple-trait varieties]

	1996	1999	2002	2005	2006	2007	2008
-------------------All Herbicide-Tolerant Varieties-------------------							
Corn	3%	8%	11%	26%	36%	52%	63%
Soybeans	7.4%	55.8%	75%	87%	89%	91%	92%
Cotton	0.2%	44%	74%	81%	86%	92%	93%
-------------------All *Bt* Crop Varieties-------------------							
Corn	1.4%	25.9%	24%	35%	40%	49%	57%
Cotton	12%	31%	39%	60%	65%	72%	73%
Data Source: Supplemental Tables 2-4							

standing worries over pesticide use and risk, both in the U.S. and Europe.

In part for this reason, there has been surprisingly little rigourous independent analysis of the pesticide use implications of GE crop technology. This lack of solid data is all the more surprising given that: 1) nearly all commercially grown GE crops have pest management traits that directly impact pesticide use practices; and 2) the technology is being implemented and promoted by agrichemical firms that have acquired a significant share of the world's seed supply.

This report attempts to fill an important gap in understanding of the impacts of GE crop technology by answering the following question: How have GE crops impacted pesticide use in the United States? We begin by providing brief overviews of the two major traits introduced into the three primary GE crops: herbicide tolerance and insect resistance in corn, soybeans, and cotton. **GE crops with these traits comprise roughly 99% of all biotech crops grown (by acreage) in the U.S. from 1996 to 2008.**[3]

Herbicide Tolerance

Herbicide-tolerant (HT) crops are engineered to survive direct "post-emergence" application of one or more herbicides. The herbicide kills or severely stunts all or most growing weeds, while leaving the crop undamaged, or just modestly impacted for a short period of time.

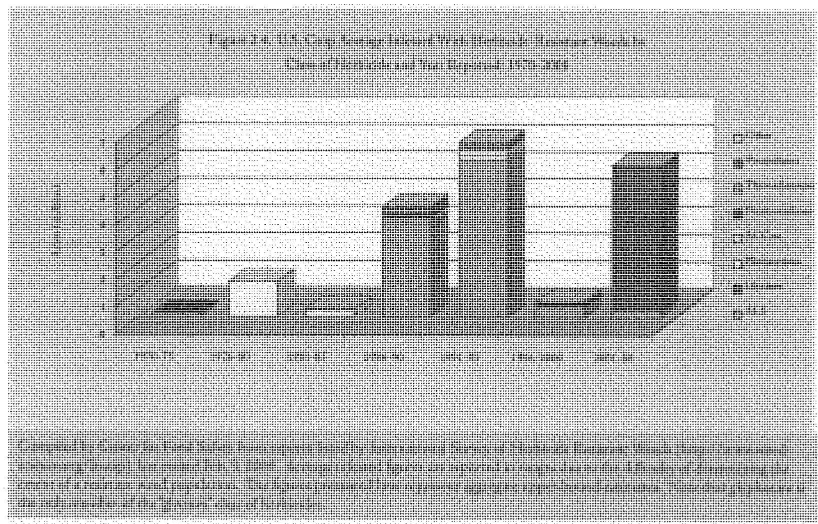
A handful of HT crops was introduced prior to the advent of genetic engineering. The first such crop, canola resistant to atrazine and related triazine herbicides, was commercialized in 1984. Interestingly, it was developed through recurrent backcrossing of canola with a related weed (*Brassica campestris*) from a population that had previously evolved resistance in the field through repeated application of triazine herbicides.[4] Most other non-GE HT crops were developed through use of mutagenesis to be resistant to sulfonylurea and/or imidazolinone herbicides that inhibit the acetolactate synthase enzyme (ALS inhibitors). ALS inhibitor-resistant corn, soybeans, and canola were commercialized in 1992, 1994, and 1997, respectively, followed in the early years of this decade by resistant varieties of wheat, rice and sunflower.[5]

It is worth noting that these crops were endowed with resistance to the two classes of herbicides to which weeds, at the time, had developed the most widespread resistance, in terms of both number of resistant biotypes and acreage infested. The first major wave of herbicide resistance that began in the 1970s involved 23 species of weeds resistant to atrazine and related herbicides of the photosystem II inhibitor class, which have been reported to infest up to 1.9 million acres of cropland in the U.S. The second major wave began in the 1980s, and involves 37 species of weeds resistant to ALS inhibitors. Scientists have confirmed that these resistant weeds now infest up to 152,000 sites covering 9.9 million acres (see Figure 2.4).

3 GE canola has been planted on no more than 1 million acres annually; GE papaya is grown only in Hawaii on roughly 1,000 acres (and no where else in the world); the acreage of GE squash is unknown but almost certainly miniscule. GE sugar beets were not planted on a commercial scale until 2009.

4 Tranel, P. J., and Horvath, D. P., (2009). "Molecular biology and genomics: new tools for weed science," *Bioscience* 59(3): 207-215, p. 208.

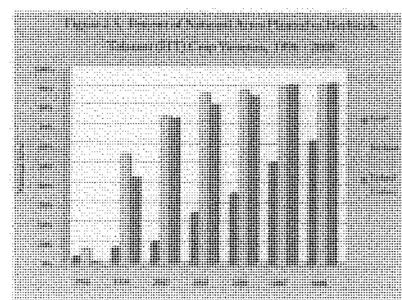
5 Tranel and Horvath (2009), *op. cit.*, Table 1.



Though acreage figures are difficult to come by, a market research firm recently estimated that non-GE herbicide-resistant crops were planted on roughly 6 million acres in 2007.[6] It was not until the advent of genetic engineering that HT crops became prevalent. This report deals only with GE HT crops.

GE HT soybeans, cotton, and corn were introduced beginning in 1996 on just over 7 million acres, and their use expanded by nearly 20-fold to cover more than 132 million acres by 2008. In 2008, HT soybeans, cotton, and corn represented 92%, 93%, and 63% of total acres planted to each crop, respectively (see Figure 2.5, Table 2.2, and Supplemental Tables 2-4 for details and sources).

The vast majority of HT crops are Monsanto's glyphosate-resistant, Roundup Ready (RR) soybeans, cotton, and corn. GE bromoxynil-tolerant (BXN) cotton was planted on modest acreage from the mid-1990s until 2004, but has since disappeared from the market (see Supplemental Table 4). The only currently grown GE crops resistant to an herbicide other than glyphosate are glufosinate-resistant cotton, corn, and canola, which are sold under the brand name LibertyLink (LL). However, LL varieties are not widely grown, comprising no more than a few percent of U.S. cotton and corn acres.[7]



6 Doane Market Research and Biotech Traits Commercialized: Outlook 2010, as cited in USDA APHIS (2008). "Finding of No Significant Impact on Petition for Nonregulated Status for Pioneer Soybean DP-356043-5," USDA's Animal and Plant Health Inspection Service, July 15, 2008, Response to Comments, p. 26. http://www.aphis.usda.gov/brs/aphisdocs2/06_27101p_com.pdf

7 For LibertyLink cotton, see Supplemental Table 4; for LibertyLink corn, see Chapter 4(B).

A major factor driving adoption of glyphosate-resistant (GR) crops has been the declining efficacy of popular ALS inhibitors. Control problems emerged with ALS inhibitors as a result of the development of resistant weeds beginning in 1987, just five years after the first ALS inhibitor herbicide was brought to market in 1982.[8] As noted above, weeds resistant to ALS inhibitors were more prevalent than any other class of herbicide-resistant weeds in the U.S.

Another reason for the dominance of RR crop systems is ease of use and the efficacy of glyphosate, an herbicide that kills a broad spectrum of weeds including annual and perennial broadleaf and grass species. RR-based cropping systems have been well received by farmers because they are simple, flexible, and forgiving.

Prior to the commercial introduction of RR HT crops, glyphosate use was restricted to either before a crop was planted or new seedlings have emerged, or after a crop was harvested. Any direct applications on a growing crop were certain to cause significant damage. RR technology widened the application window to allow post-emergence applications over the top of growing plants throughout the season, thus leading to dramatically increased use of and reliance on glyphosate-based herbicides. As discussed further below, RR crop systems have fostered a third wave of resistant weeds that poses a serious threat to agriculture, and are also profoundly shaping the biotech industry's product pipeline. As yet, there has been no regulatory response to the growing epidemic of GR weeds.

Insect Resistance

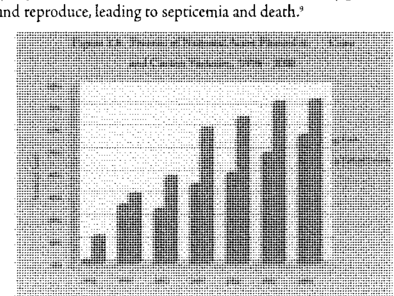
In contrast to herbicides, insecticide use in American agriculture has declined sharply since the mid-1960s as a result of the shift away from chlorinated hydrocarbon and carbamate insecticides applied at about one pound per acre, to synthetic pyrethroid and other insecticides applied at one-half to one-tenth pound per acre, or less.

Insect-resistant cotton and corn varieties are genetically modified to produce one or more truncated and activated forms of the toxins (e.g., Cry1Ab) derived from the soil bacterium *Bacillus thuringiensis* (*Bt*). These so-called *Bt* crops were introduced in 1996, and the percentage of national crop acres planted has grown rapidly, as shown in Figure 2.6.

Acreage planted to *Bt* crops grew from 1.8 million acres of cotton in 1996 to 55.8 million acres of corn and cotton in 2008, as shown in Supplemental Table 6. The first *Bt* corn varieties, and all *Bt* cotton varieties, repel above-ground Lepidopteron pests such as the European corn borer (ECB), Southwestern corn borer (SWCB), and cotton bollworm. *Bt* corn to control corn rootworm (CRW) and other soil-borne insects was introduced in 2003.

Bt toxins are biosynthesized continuously throughout the tissues of *Bt* plants, although genetic engineers have some ability to preferentially target (i.e., increase) expression levels in those plant tissues where the toxin is most needed to fend off insect feeding. *Bt* plant-incorporated toxins exert profound selection pressure for development of resistant insects by virtue of the plant's continual production of toxin, in contrast to the intense but short-lived exposure characteristic of *Bt* insecticidal sprays.

The mode of action of *Bt* sprays and toxins is not completely known. Foliar *Bt* sprays contain inactive Cry protoxins (about 130-140 kDa in size) which exist in a crystalline form, when ingested. The alkaline nature of the fore- and mid-gut dissolves the crystal and cleaves it one or two times in the fore and mid-gut to create a truncated, activated toxin (about 60-65 kDa in size). The ***activated*** Cry toxins poke a hole in the gut epithelium, but it is unclear what causes insect death. The two proposed mechanisms are: 1) disruption of the mid-gut epithelium causes insects to stop feeding and starve to death, or 2) extensive cell lysis provides the *Bt* access to the hemocoel, where they germinate and reproduce, leading to septicemia and death.[9]



[8] Tranel, P.J., and Wright, (2002.),"Resistance of weeds to ALS-inhibiting herbicides: what have we learned?" *Weed Science* 50:700-712.

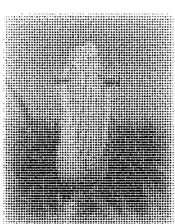
[9] Broderick, N.A. et al (2006). "Midgut bacteria required for *Bacillus thuringiensis* insecticidal activity." *Proceedings of the National Academy of Sciences*, 103(41): 15196-15199.

The toxicity of *Bt* sprays is limited to those insects with the alkaline gut pH required to cleave and activate the protoxin. In *Bt* plants, the Cry toxins are already activated, increasing the potential for adverse impacts on populations of beneficial insects.[10]

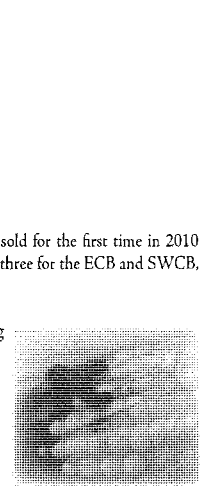
Even before their commercial introduction, many scientists were concerned that *Bt* crops would accelerate the evolution of pest resistance to *Bt* toxins.[11]

In response to such clear warnings from scientists and in the hope of delaying the emergence of resistance, the EPA mandated that *Bt* cotton and corn growers plant blocks of conventional (non-*Bt*) crop "refuges" amidst *Bt* fields to help slow development of resistance. Refuges work by maintaining populations of susceptible insects, some of which will mate with resistant insects, thereby diluting the presence of *Bt*-resistant genes in insect populations. EPA encourages "high-dose" *Bt* crops as another resistance management strategy; high levels of expression of *Bt* toxins lead to a more complete kill of target insects, and hence fewer surviving insects with the potential to pass along resistant genes.

The resistant management plans imposed by EPA on *Bt* cotton and corn have, for the most part, been effective. However, continued vigilance is necessary, given the emergence of isolated populations of cotton bollworms resistant to Cry1Ac in *Bt* cotton.[12]



Seed companies have also begun developing *Bt* crops with multiple *Bt* toxins, both to expand the range of insects controlled and as a resistance management strategy. *Bt* corn with toxins for both ECB and CRW (e.g., YieldGard Plus) were introduced in 2005, and are now widely planred. Cotton with two *Bt* toxins (Bollgard II) was introduced in 2003, and SmartStax corn varieties will be sold for the first time in 2010 expressing six different *Bt* toxins, three for the ECB and SWCB, and three more for the CRW.



New issues arise in assessing risks associated with the stacked versions of crops that have more than one Cry protein. There may be a synergistic effect between the various Cry proteins which could affect the efficacy of the various Cry proteins against their target and non-target organisms. Cross-resistance could emerge as a new challenge in managing resistance. Additional data will also be needed for human toxicity and environmental effects.[13] For instance, the EPA recently funded research to develop an animal model of allergenicity to better assess the potential for *Bt* insecticidal proteins to trigger food allergies.[14]

C. Data Sources and Complications

This report is based on surveys of agricultural chemical use conducted by USDA's National Agricultural Statistics Service (NASS). We chose to base this analysis on USDA data for several reasons. First, NASS supplies highly reliable data through use of transparent, rigorous methods and statistically representative sampling procedures.[15] Second, because the NASS program has collected annual pesticide usage data on soybeans, corn, and cotton for most of the years covered by this report, it offers a consisrent dataset that facilitates accurate, year-to-year comparisons. Finally, the public availability of NASS data (free of charge) facilitates open review and criticism of any analysis utilizing them.

NASS data are considered the gold standard of pesticide use information in the U.S. NASS reports provide a solid basis to study trends in the intensity of pesticide use across crops and

10 For more on *Bt* modes of action, including differences re: target and non-target species, see: Then, C. (2009), "Risk assessment of toxins derived from Bacillus thuringiensis—synergism, efficacy, and selectivity," *Environ Sci Pollut Res*, Access at: http://www.springerlink.com/content/a42th8677132802g/fulltext.pdf Published online June 26, 2009.

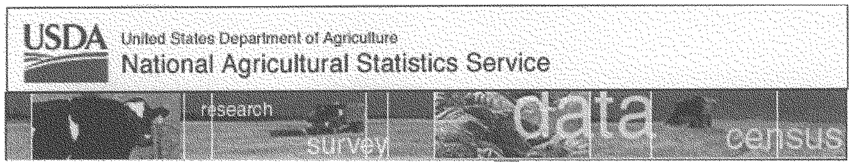
11 Harris, M. K. (1991). "Bacillus thuriengensis and Pest Control," Letter to *Science*, Vol. 253, September 6.

12 Tabashnik, B.E., et al (2008). "Insect resistance to *Bt* crops: evidence versus theory," *Nature Biotechnology* 26(2): 199-202.

13 For a recent report on additional data needs for *Bt* proteins, see http://www.epa.gov/scipoly/sap/meetings/2009/february/022526finalreport.pdf

14 EPA (2009). "EPA grant to University of Chicago for research on food allergy triggers," EPA Press Release, at http://www.epa.gov/ncer/events/news/2009/07_28_09_feature.html July 23.

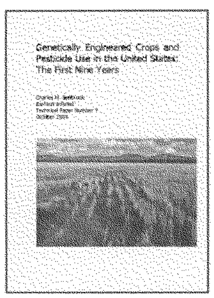
15 USDA NASS (2006). "Meeting of the Advisory Committee on Agriculture Statistics (ACAS): Summary and Recommendations," USDA National Agricultural Statistics Service, Appendix III, at: http://www.nass.usda.gov/About_NASS/Advisory_Committee_on_Agriculture_Statistics/advisory-es021406.pdf February 14-15, 2006.



regions, among pesticide families of chemistry, and over time. These reports are a valuable resource used by EPA and state pesticide regulatory agencies, farm commodity groups, the food industry, environmental and consumer groups, and the pesticide industry.

Several private firms[16] also collect pesticide use information, under contract with mostly corporate subscribers, such as agrichemical companies. These sources are unacceptable for use in this report for several reasons, including their great expense, the proprietary nature of sampling methodologies, and prohibitions on the use and/or disclosure of purchased data.[17]

Because USDA does not routinely collect separate data for pesticide use on GE and conventional crops, a methodology is needed to estimate average pesticide use on GE and conventional crop acres. Such a methodology was first developed in 2003 and used in the analysis reported in Ag BioTech InfoNet Technical Paper #6, "Impacts of Genetically Engineered Crops on Pesticide Use in the United States: The First Eight Years."



The method was refined and applied to an additional year of USDA pesticide use data in the October 2004 Ag BioTech InfoNet report "Genetically Engineered Crops and Pesticide Use in the United States: The First Nine Years."[18] The same basic approach has been applied in this analysis covering the first 13 years of commercial planting of GE crops.

USDA has surveyed pesticide use for five decades beginning in 1964. Subsequent national surveys were conducted in 1966, 1971, and 1982. These early surveys covered only a few major crops and collected just basic data like the percentage of acres treated and pounds of active ingredient applied.

From 1991 through 2001, NASS surveyed pesticide use on major field crops including corn, soybeans, and cotton on an annual basis. Annual summary reports have been issued with a set of tables covering pesticide use in all "Program States,"[19] as well as at the national level.

Each standard table for a given crop reports the percentage of acres treated with a specific pesticide active ingredient, the average rate of application in pounds of active ingredient per acre; the average number of applications; the average rate per crop year, which is simply the one-time application rate multiplied by the number of applications; and the total pounds applied.

Benbrook Consulting Services (BCS) and Ecologic, Inc. have moved NASS survey data into a database program to carry out additional computations. For instance, average figures for individual and aggregate pesticide use in the Program States are applied to the small proportion of acres that NASS does not survey to arrive at estimates of total pesticide use for all crop acres in any given year.[20]

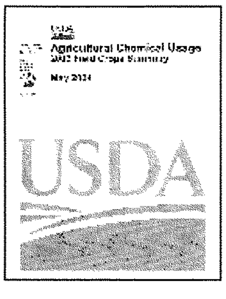
16 For instance, Doane Marketing Research and Crop Data Management Systems.

17 USDA NASS (2006), *op. cit.*

18 Access this 2004 report at http://www.organic-center.org/science.latest.php?action=view&report_id=158

19 "Program States" are those surveyed that year by NASS, and typically represent 85% or more of the national acreage planted to a given crop.

20 This is accepted practice, e.g. see "Agricultural Resources and Environmental Indicators: Pest Management Practices," USDA Economic Research Service, Report No. AH722, September 2000, Table 4.3.1, footnote 1, accessible at http://www.ers.usda.gov/publications/arei/ah722/arei4_3/DBGen.htm. "The estimates assume that pesticide use on acreage in non-surveyed States occurred at the same average rate as in the surveyed States."



In years when a given crop was not surveyed by NASS (e.g., cotton in 2006), average values are interpolated between the previous and following year to fill in such data gaps. For corn since 2005, soybeans since 2006, and cotton for 2008, herbicide and insecticide use rates were projected from recent trends and in light of published reports on university websites regarding levels of pest pressure and the emergence of resistant weeds or insects.

Spikes upward in pesticide use are readily apparent in NASS data and have alerted farmers, scientists, and USDA to pest-induced problems in specific crops and regions. Such problems might be triggered by the emergence of resistance to a once-effective pesticide or the introduction of a new invasive species. Likewise, reductions in the frequency and intensity of pesticide use are regarded as evidence that farmers have made progress in adopting prevention-based Integrated Pest Management (IPM), perhaps through the planting of a new crop variety or adoption of a more complex crop rotation.

By combining NASS pesticide use data with EPA data on the toxicological potency of pesticide active ingredients, pesticide risk indices specific to different classes of organisms, like birds or bees, have been calculated by the Economic Research Service (ERS) and other analysts. Such indices provide a useful early-warning system to detect changes in pest pressure, or pesticide efficacy over time and in different regions that may lead to "unreasonable adverse effects on man or the environment," the basic standard embedded in U.S. pesticide regulatory policy.

Scientists studying the emergence of resistance to a specific pesticide, or family of chemicals, rely heavily on pesticide-use data to determine the degree of selection pressure required to trigger resistance.[21] Epidemiologists exploring associations between pesticide use, exposure and patterns in birth defects or cancer often use NASS data in constructing retrospective estimates of exposure levels.

21 For instance, see: Owen, M. D. K., and Zelaya, I. A., (2005). "Herbicide-resistant crops and weed resistance to herbicides," *Pest Manag* Sci 61: 301-311.

Impacts of USDA Decision to Stop Collecting Pesticide Use Data

NASS has dramatically scaled back its program in recent years. First, NASS replaced its annual surveys of major field crops with less frequent ones beginning in 2002. Then, in the 2007 growing season, data collection was limited to just two crops—cotton and apples. NASS did not collect pesticide use data on any crops during the 2008 growing season, citing a shortage of funds and the availability of private sector survey data as reasons for cutting the program.[22]

Of the three major crops covered in this report, NASS data are available in most years for cotton through 2007, through 2006 for soybeans, and through 2005 for corn.

The absence of a continuous series of NASS data since 2005 for the three major GE crops hampers the ability of independent analysts and government scientists to track the performance and impacts of GE crops. The lack of NASS pesticide-use data covering recent crop years is a special concern, given the dramatic impact of resistant weeds on the number and volume of herbicides applied to HT crops.

USDA's decision to drop the pesticide-use surveys led to strong protests from a wide range of groups, including The Organic Center, Center for Food Safety, Union of Concerned Scientists, Natural Resources Defense Council, and many other organizations, including several with close ties to the pesticide industry.[23] In 2008, the administrator of the EPA voiced concern to the Secretary of Agriculture about the loss of NASS data, joining several government officials at the state and federal levels. In May, 2009, the new USDA leadership announced the reinstatement of the program, beginning with the fruit and nut survey in the fall of 2009.[24]

22 Engelhaupt, E. (2008). "Government pesticide and fertilizer data dropped," *Environ. Sci. Techol.* 42(18), 6779-6780, at: http://pubs.acs.org/doi/pdfplus/10.1021/es801937k?cookieSet=1.

23 For a press release with a link to the letter from 44 organizations to former Secretary of Agriculture Ed Schafer, see http://truefood-now.wordpress.com/files/2009/10/usda-nass-pr-final-without-hy-perlinks.doc.

24 Letter of May 7, 2009 from Katherine Smith, Acting Deputy Under Secretary for Research, Education, and Economics, to Dr. Charles Benbrook, The Organic Center.

D. Methodology

In this report a four-step methodology is used to calculate the differences in the amount of pesticides applied to GE crops versus conventional crops in a given year.

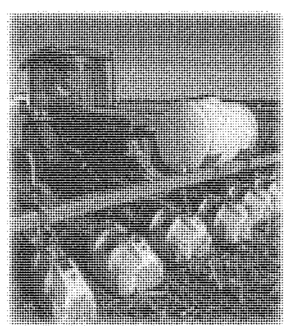
First, the total number of acres of each crop planted to conventional, HT and/or *Bt* varieties is derived from standard USDA sources: NASS for soybeans and corn, the Agricultural Marketing Serviee (AMS) for cotton.

Monsanto's "Biotechnology Trait Acreage" reports are used to disaggregate total *Bt* corn trait acres to those planted to varieties engineered to control the ECB, the CRW, or both.

Second, the average amount of pesticides applied per acre per crop year is estimated for conventional GE crop acreage (detailed results in Supplemental Table 7).

Third and by year, the average amount of herbicides or insecticides applied to an acre planted to a conventional seed variety is subtracted from the corresponding amount for the GE crop.

Finally, in the **fourth** step, the difference in pesticide pounds applied per acre for each GE trait is multiplied by the acres planted to the GE crop in that year (full results appear in Supplemental Table 8). The impacts of herbicide tolerant and *Bt* crops on pesticide use per acre are then added together across the three crops over the 13 years of commercial use, producing the overall impact of today's major GE crops on herbicide, insecticide, and all pesticide use.



Estimating Herbicide Application Rates on Conventional and HT Soybeans, Corn, and Cotton

Because the USDA does not report herbicide-use data separately on acres planted to conventional varieties, in contrast to GE varieties, an indirect method was developed that draws on NASS data. The method involves the use of a standard formula to estimate what is not known, from variables that are known from NASS and other data sources.

The average pounds of herbicides applied on all corn, soybean, or cotton acres in a given year are easily calculated from NASS data. Data are readily accessible on the share of total crop acres in a given year that were planted to conventional crop varieties, as well as the percentage planted to GE varieties. These two percentages add up to 100% and can be used in a weighted-average formula, along with average herbicide use on GE crop acres, to calculate the pounds of herbicides applied on non-HT acres.

The basic weighted average formula, as applied to the pounds of herbicides used in producing HT and conventional acres of $crop_X$, contains the following five data elements, the first four of which are known or can be projected from USDA.

1. Average herbicide use per acre on all acres planted to a crop, from NASS surveys;

2. The percentage of acres planted to HT crops, from ERS and AMS data;

3. The percenrage of acres planted to conventional varieties (100% minus number 2);

4. The average pounds of all herbicides applied per acre of HT crop, from NASS surveys and university sources; and

5. The average pounds of herbicides applied per acre of conventional crop, which can be calculated by solving the weighted-average equation for the variable"Ave. Pounds Applied on non-HT acres $crop_X$."[25]

[25] The weighted-average formula can be used to calculate average herbicide use on conventional crop acres by subtracting the term (% acres planted to HT varieties $crop_X$ x Average Pounds Applied on GE varieties $crop_X$) from both sides of the equation, and then dividing by the percentage of crop acres planted to non-GE varieties.

The basic formula is:

Average Herbicide Pounds Applied per Acre on All Acres of $crop_X$ =

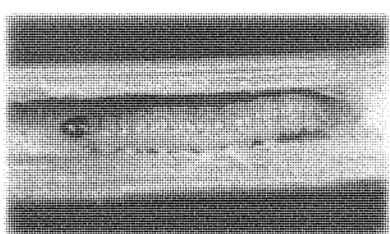
(% acres planted to HT varieties $crop_X$ x Ave. Pounds Applied on HT varieties $crop_X$) +

(% acres planted non-HT varieties $crop_X$ x Ave. Pounds Applied on non-HT acres $crop_X$)

For a given crop and year, we calculated the impact of HT technology on herbicide use by subtracting the average rate applied to conventional acres (number 5 in above list) from the average rate applied to HT acres (number 4 in above list). When this number is negative, HT technology reduced herbicide use in that year for that crop; when it is positive, average herbicide use was higher on HT acres.

Insecticide Application Rates on Conventional and *Bt* Corn and Cotton Acres

In the case of *Bt* corn, two steps are required to estimate the impact of an acre planted to *Bt* corn for ECB/SWCB and/or CRW control on corn insecticide use. First, the average rate of application per crop year must be calculated for insecticides targeting the ECB and the CRW. This process is complicated by the fact that several insecticides are applied for control of both the ECB and CRW. For these insecticides, the portion of acres treated for control of ECB versus the CRW must be estimated. We reviewed pesticide labels, treatments recommended in university spray guides, and consulted with experts in corn IPM in carrying out this step (see Supplemental Table 9 for the share of insecticide acres treated targeting the ECB and Supplemental Table 10 for the share targeting the CRW).



The percentage of national corn acres treated with each insecticide for ECB/SWCB and CRW control was used to calculate a weighted average rate of insecticide application across all corn acres treated per crop year. Based on these calculations, the weighted average rate of insecticides applied on conventional acres for ECB control drops from 0.2 pounds of active ingredient per acre in 1996 to 0.15 in 2005-2008. In the case of CRW, the rate of insecticides applied on conventional acres falls from 0.29 pounds per acre in 2003, the year *Bt* corn for CRW control was commercialized, to 0.19 pounds in 2005-2008. Figure 2.7 shows the weighted-average rate of application for insecticides targeting the ECB and CRW.

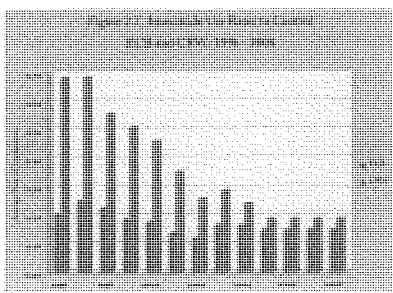
The second step in calculating the pounds of insecticides displaced by the planting of *Bt* corn is to estimate the portion of acreage planted to *Bt* corn for ECB and/or CRW control that would have been treated with an insecticide if the corresponding *Bt* crop had not been planted. This step is required since *Bt* corn is now planted on far more acres than were ever treated with insecticides. Historically, USDA data show that before the advent of *Bt* corn, just 6% - 9% of national corn acres were typically treated for ECB/SWCB control, while 27% +/- 4% were treated for CRW control.

Supplemental Table 11 provides the details of this step and the resulting estimates of insecticide use averted through the planting of *Bt* corn for ECB and/or CRW control.

In the case of *Bt* acres targeting the ECB/SWCB, the likely share of acres planted to *Bt* corn that would have been sprayed for ECB control begins at 90% in 1997, the first year of commercial planting, and drops incrementally to 45% in 2008, a year when over half of corn acres were planted to a *Bt* corn variety engineered for ECB control.

The high initial percentage is based on the assumption that early adopters of *Bt* ECB corn were more likely to have been farmers contending with serious ECB and/or SWCB infestations, triggering the need for insecticide applications. The falling percentage reflects the progressively wide adoption of *Bt* corn by farmers with lesser ECB/SWCB problems, many of whom likely did not spray prior to the commercial launch of *Bt* corn.

In the case of *Bt* corn for CRW control, the percentage of acres planted that would likely have been treated with an insecticide targeting the CRW begins at 95% in 2003, the first year of commercial sales, and declines to 60% in 2008, a year when 35% of corn acres were planted to a *Bt* corn for CRW control and another 9% of corn acres were sprayed for CRW control with an insecticide (i.e., about 44% of corn acres were either sprayed or planted to a *Bt* variety for CRW control, well above the 27% +/- 4% level treated with insecticide for CRW from 1964 through 2008).



This higher projected level of CRW treatment of corn acres is justified in part by the emergence in the late 1990s of a variant of the CRW that learned to overwinter in soybean fields, thus undermining the efficacy of corn-soybean rotations in reducing CRW populations.

Bt cotton targets the budworm/bollworm complex, but does not appear to have significant effects on other insect pests, including the boll weevil, plant bugs, white flies, and stink bugs. Growers typically apply broad-spectrum insecticides to control both the budworm/bollworm complex and other insects. *Bt* cotton will reduce the use of insecticides for budworm/bollworm complex, but not applications of insecticides targeting other insects.

Supplemental Table 12 reports the basis for estimating the pounds of insecticides averted by each acre planted to *Bt* cotton. First, university insect management guides and experts were consulted to estimate the portion of total acres treated with each cotton insecticide for control of the budworm/bollworm complex versus other insects. Then the number of acres treated with each insecticide is calculated from NASS data, as well as the share of total acres treated that was accounted for by a given insecticide.

Finally, weighted average use rates were calculated using the shares of total acre treatments with each individual insecticide. In the case of cotton, this weighted average insecticide application rate falls modestly from 0.56 pounds per acre in 1996 to 0.47 in 2007-2008.

E. Assumptions and Caveats

The methodologies used to project pesticide use on conventional and GE-crop acres require a number of assumptions and projections. Here, a brief description is provided of the major assumptions embedded in the Supplemental Tables that form the operating core of the model used to estimate the impact of GE crops on pesticide use. Each assumption or projection is also assessed in terms of its impact on our analysis of pesticide-use levels.

1. Farmers planting GE-crop varieties take advantage of the novel traits they are paying for.

For example, in the case of herbicide-tolerant plants, it is assumed that farmers build their weed management program around glyphosate herbicide. Likewise, a farmer purchasing a stacked-trait corn or cotton variety will alter both weed and insect pest management systems in accord with the purchased traits.

These assumptions closely reflect reality up to the 2009 crop season, but may not in the future as the seed industry moves toward more multiple-trait stacked varieties.

2. A small acreage of corn and cotton planted to GE herbicide-tolerant varieties other than those resistant to Roundup are included in the herbicide-tolerant acreage estimates from the NASS and AMS. Herbicide use on these non-RR acres, however, is analyzed as if the acres were planted to a RR variety.

Perhaps 15 million acres have been planted to non-RR HT varieties over the last 13 years, a period during which approximately 941 million acres of RR crops have been planted. Accordingly, these non-RR HT acres account for just one out of every 63 acres of HT crops. In addition, the differences in herbicide use on non-RR HT crops, compared to RR crops, are modest. As a result, this assumption has virtually no impact on the outcome of the analysis.

3. Bt-crop growers apply no chemical insecticides for the pests targeted by these trait(s): ECB/SWCB and CRW, and the budworm/bollworm complex.

This assumption assumes close to 100% control of target pests, and overstates efficacy in regions with high pest pressure, especially where multiple generations of target pests are common. As a result, the displacement of insecticide use is likely overstated in the case of some acres planted to *Bt* crops. For example, University of Illinois entomologists have documented spotty performance of *Bt* corn for CRW control, especially under high population pressure, and reported that some growers have applied soil insecticides on *Bt*-corn acres.[26]

In fact, there was so much farm press media attention on the benefits of applying a soil insecticide on corn acres planted to a *Bt* corn for CRW control that the top entomologists in the University of Illinois felt compelled to ask – and answer "No" to - the following question in a widely read bulletin for growers:

> "Does it **always make sense** to use a soil insecticide in conjunction with a *Bt* [CRW] Hybrid?"[27]

Accordingly, this assumption overstates the reduction in insecticide use on some *Bt* corn acres. But because corn insecticides are applied at relatively low rates, the impact of this assumption is modest. This could change dramatically, of course, if resistance emerges to the *Bt* toxins engineered into corn for CRW control, and farmers are forced to apply higher-rate insecticides to prevent serious CRW feeding damage.

4. *It is possible to estimate the shares of the pounds applied of a given, broad-spectrum insecticide across multiple target insects, so that these shares can be used in estimating the rate of insecticide applications displaced by a given Bt trait.*

Bt varieties have many complex impacts on insect communities and populations. In some fields, lessened insecticide use allows secondary pests to reach damage thresholds, triggering the need for additional insecticide sprays.[28] In other fields or perhaps in certain years, the reduction in insecticides targeting key Lepidopteron insects creates an opening for populations of beneficial insects, like assassin bugs, to expand, increasing the effectiveness of biological control, and reducing the need for insecticides.

Several broad-spectrum insecticides applied by corn and cotton growers help manage multiple insects, including some which are, and others which are not, the target of the *Bt* toxins engineered into *Bt* corn and cotton varieties. Thus, crediting *Bt* corn for ECB/SWCB control with displacement of all the pounds of organophosphate or synthetic pyrethroid insecticides applied would overstate the impacts of the technology, since a portion of most of these insecticides are applied by farmers for the control of other insects, including the CRW.

Through consultation with insect pest management guides and entomologists, these shares were approximated for the key target pests of *Bt*-crop varieties. In some cases the shares used in the model likely overestimate displacement, while in others, displacement is likely underestimated. Given that most insecticides now applied to corn and cotton acres are low-dose products, discrepancies in these shares will have a modest impact on the pounds of insecticides displaced by *Bt* crops, especially relative to changes in the pounds of herbicides applied on HT acres.

5. *Some portion of the acres planted to Bt corn do not displace insecticides because before the commercial availability of Bt-corn seed, farmers were not treating their fields with insecticides.*

Historically, around 35% +/- 4% of corn acres have been treated each year with an insecticide for control of the ECB, SWCB, CRW, and other insect pests. In 2008, 57% of corn acres were planted to a *Bt* variety, including many acres planted to a dual-*Bt* variety. For this reason, crediting each acre of corn planted to a single *Bt* trait with displacement of an insecticide acre treatment would substantially

26 Steffey, K., (2007). "*Bt* Corn + Soil Insecticide: What?", *The Bulletin*, University of Illinois Extension, No. 23, Article 4, October 5.

27 "Preliminary Node-Injury Ratings from University of Illinois Rootworm Product Efficacy Trials Near DeKalb, Monmouth, Perry, and Urbana,", *The Bulletin*, University of Illinois Extension, No. 23, Article 3, October 3, 2008.

28 Caldwell, D. (2002), "A Cotton Conundrum," Perspectives, OnLine: The Magazine of the College of Agriculture and Life Sciences, North Carolina State University, http://www.cals.ncsu.edu/agcomm/magazine/winter02/cotton.htm Winter 2002,

overestimate the reduction in insecticide use attributed to the technology.

As previously noted, corn insect pressure, however, has also changed in recent years as a result of the emergence of a new subspecies of the CRW that overwinters in soybean fields and disrupts the efficacy of the corn-soybean rotation in reducing CRW populations.

This variant of the CRW was taken into account by increasing the share of *Bt*-corn acres assumed to displace insecticide applications to well above historic levels of insecticide use. The projections of *Bt* corn impacts on insecticide use reflect a near doubling of the percentage of acres that farmers would likely spray with an insecticide, in the absence of *Bt* corn.

This assumption likely leads to a modest overestimate of the displacement of insecticide use caused by *Bt* corn, since corn farmers have other proven alternatives to reduce CRW populations through IPM systems. Regrettably, some corn farmers have lost interest in the multi-tactic approaches used in successful IPM systems as one consequence of the planting of *Bt* corn.

6. The Bt toxins manufactured within the cells of Bt crops are not counted as insecticides "applied" on Bt-crop acres.

Clearly, this assumption underestimates the pounds of insecticidal compounds required to manage insects on *Bt* crop acres. Opinions differ among entomologists, the industry, and other experts on whether it is appropriate to count *Bt* toxins manufactured inside GE plants as equivalent to a liquid *Bt* insecticide sprayed on the outside of the plant. Uncertainty over the exact mode of action of *Bt* insecticides and GE toxins is part of the reason for differing opinions.

Those who argue that plant-manufactured *Bt* toxins should not count as equivalent to an applied insecticide assert that a *Bt* variety is just like any other new plant variety that has been bred to express some plant protein or phytochemical useful in combating insect-feeding damage.

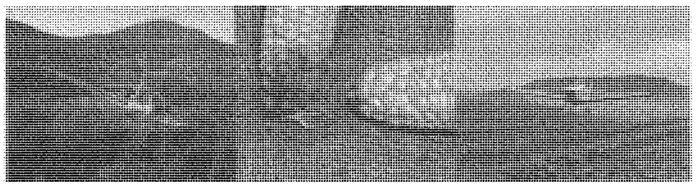
Those skeptical of this position point to major differences in the two *Bt* delivery systems and in the source of the *Bt* toxin. *Bt* liquid sprays are applied only when and as needed, consistent with the core principles of IPM. Liquid sprays expose pest populations to short-lived selection pressure, thereby reducing the risk of resistance.

Bt plants, however, produce the toxin continuously during the growing season, not just when needed, and in nearly all plant tissues, not just where the toxins are needed to control attacking insects. In a year with low pest pressure, farmers can decide not to spray insecticides on a corn field, but they cannot stop *Bt* hybrids from manufacturing *Bt* toxins in nearly all plant cells.[29]

There is another key difference that rarely is acknowledged. When plant breeders develop a new variety with a higher level of resistance to a given insect through traditional breeding techniques, they do so by selecting a top-yielding variety to crossbreed with another variety that expresses relatively higher levels of natural phytochemicals that discourage pest feeding, disrupt pest development or reproduction, or in some way reduce the viability of pest populations.

It is extremely rare for a new crop variety developed through conventional breeding to reduce insect feeding damage by killing the target insects. Instead, the elevated levels of phytochemicals in the new variety work through one or more non-toxic modes of action.

29 Moreover, from a food safety perspective, *Bt* toxins in liquid sprays break down relatively quickly in the field when exposed to sunlight and hence do not end up in the harvested portion of crops. *Bt* toxins in GE plants are inside plant cells, including the cells of the harvested portion of the crop fed to animals or consumed by people.



This is a second reason why some entomologists reject the notion that there is nothing different between a crop variety genetically engineered to synthesize *Bt* toxins within plant cells, and a new variety from conventional breeders that has improved resistance to an insect pest because of altered levels of natural phytochemicals that work through a non-toxic mode of action.

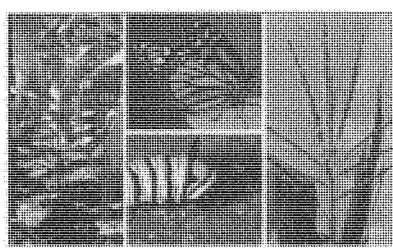
No resolution is in sight for this complex debate within the entomological community. In addition, no method exists to estimate the pounds of *Bt* toxins produced by a corn or cotton plant during a growing season. Hence, there is no way to project the pounds of *Bt* produced by an acre of *Bt* corn or cotton. Work is needed to develop such a methodology. It will likely show that there is a surprisingly large amount of toxin synthesized by plants during a typical growing season, especially in the new corn varieties engineered to produce six *Bt* toxins.

7. The last NASS survey of soybean herbicide use was in 2006. Glyphosate application rates per crop year on soybeans are projected to increase 5% annually from 2006-2007 and from 2007-2008. Cotton was surveyed last in 2007, and the glyphosate rate was projected to increase 10% from 2007-2008. Corn was last surveyed in 2005, and the glyphosate and total herbicide rates per crop year are projected to increase 5% annually since 2005.

These assumptions are likely conservative in the case of soybeans and cotton. In soybeans, the glyphosate rate of application per crop year rose 9.8% annually from 1996 through 2006 – almost twice the rate of increase projected in 2007 and 2008.

In cotton, the glyphosate rate per crop year rose 18.2% annually from 1996 through 2007, again well above the 10% increase incorporated in the model's projections of herbicide use on HT cotton acres in 2008.

The corn herbicide rate projections are the most uncertain, given that NASS last surveyed corn in 2005. The percentage of corn acres planted to HT varieties rose from 15% to 26% between 2003 and 2005. In this period, the rate of glyphosate applied per crop year rose on average 7.1% per year. Accordingly, the projected increase of 5% annually in the glyphosate rate per crop year in 2006, 2007, and 2008 is likely conservative. Plus, HT corn has been in widespread use now for about five years – long enough for weed shifts and resistance to begin pushing application rates per crop year upward more sharply than in the first few years of widespread commercial use.



3. Acreage Planted to GE Crop Varieties: 1996-2008

The total number of acres planted to soybeans and corn, as well as the percentage of national crop acres that were planted to an HT and/or *Bt* variety, is derived from annual NASS "Acreage" reports.[1] The USDA's Economic Research Service (ERS) has collared NASS figures on the percentage of crop acres for each GE category from 1996 to present.[2]

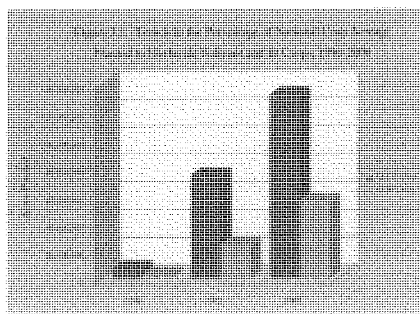
In the case of GE cotton, USDA's Agricultural Marketing Service (AMS) has a more accurate breakdown of trait categories by acreage than NASS/ERS. AMS's annual "Cotton Varieties Planted" reports[3] are favored for these data by cotton experts,[4] and also provide figures that are in closer agreement with the information on GE cotton trait acres released periodically by Monsanto.

Supplemental Table 2 reports the ERS data on the percent of corn acres by state and nationally planted to HT varieties, *Bt* varieties, and stacked varieties (one or more *Bt* genes, plus herbicide tolerance). Supplemental Table 3 covers herbicide tolerant soybeans, and Supplemental Table 4 presents both percent of national acres and absolute acreage planted to various GE cotton trait categories.

A. Acres Planted

The percent of national corn, soybean, and cotton acres planted to GE crop traits is presented in Figure 3.1. Soybean and cotton HT seeds were adopted rapidly by farmers. By 1999, 56% of national soybean acres were planted to Roundup Ready (RR) HT varieties. HT corn acres did not reach one-third market penetration until 2006.

Bt cotton reached one-third of national acres in 2000 and is currently planted on close to three-quarters of national cotton acres. It took *Bt* corn for ECB control eight years to reach one-third of national acres in the 2004 crop season. This trait is now planted on close to 50% of national acres. *Bt* corn for CRW control was introduced in 2003 and has now reached about one-third of national acres.



The acreage planted to each GE crop trait by year can be calculated by simply multiplying the percent of national crop acres planted to the GE trait in that year by the total acres of the crop grown. Table 3.1 reports the acres planted to herbicide tolerant and *Bt* transgenic varieties for corn, cotton, and soybeans in 1996, 2002, and 2008; the last column, "Total 1996-2008," includes all 13 years. The data in Table 3.1 come from Supplemental Tables 5 and 6, where HT and *Bt* crop acreage, respectively, is reported for all years.

HT crops clearly account for the lion's share of total GE trait acreage – 72% over the first 13 years of commercial use and around three-quarters in most years. HT soybeans account for almost one-half of all GE trait acres. **This is why HT soybeans are so important in terms of the overall impact of GE crops on the pounds of pesticides applied.**

As discussed in Chapter 2, we assume in this report that when a farmer purchases a variety with a given trait, the farmer relies on that trait in carrying out his/her pest management program. Yet this is not always the case, either because the trait does not perform well enough, or because it is not utilized by the farmer.

1 For instance, for 2008, see: http://usda.mannlib.cornell.edu/usda/nass/Acre//2000s/2008/Acre-06-30-2008.pdf.

2 See spreadsheet at http://www.ers.usda.gov/data/biotechcrops/ for 2000 to present. Click on the graphic for corresponding figures for entire period from 1996 to 2008.

3 For 2009, see http://www.ams.usda.gov/mnreports/cnavar.pdf.

4 For instance, see Table 1 in May, O. L. et al (2003). "Challenges in Testing Transgenic and Nontransgenic Cotton Cultivars," *Crop Science* 43: 1594-1601.

Table 3.1. Acreage Planted to Herbicide-Tolerant (HT) and *Bt* Varieties of Corn, Soybean, and Cotton

	1996	2002	2008	Total All Years: 1996-2008
HT Corn	2,385,210	8,695,940	54,168,660	219,774,911
HT Soybean	4,751,170	55,442,250	69,660,560	617,386,630
HT Cotton	23,001	10,162,074	8,609,955	104,034,840
ALL HT CROPS	7,159,381	74,300,264	132,439,175	941,196,381
Bt Corn	1,113,098	18,972,960	49,009,740	281,964,269
Bt Cotton	1,725,060	5,293,604	6,787,939	75,321,111
ALL *Bt* CROPS	2,838,158	24,266,564	55,797,679	357,285,380
ALL GE CROPS	9,997,539	98,566,828	188,236,854	1,298,481,761
HT Crops as % All GE Crops	72%	75%	70%	72%
Bt Crops as % All GE Crops	28%	25%	30%	28%

Some traits do not perform well enough to allow the farmer to completely forego pest management measures more typical of the conventional grower. For example, several Midwesrern universities have documented the need for insecticide applications to avoid serious root damage in fields planted to *Bt* corn for CRW control, and many farmers are making such applications.[5]

HT crops account for 72% of the total acreage planted to GE crop varieties from 1996 through 2008, and HT soybeans account for almost one-half of total GE acres.

In other cases, superfluous traits go unutilized. For example, corn hybrids engineered to tolerate two different herbicides are on the market, yet only one HT trait will likely be utilized by most farmers.[6] Many corn hybrids express the *Bt* gene for both ECB and CRW control, yet many farmers buying these hybrids face economically damaging levels of only one, or neither, of these insects, in most years.

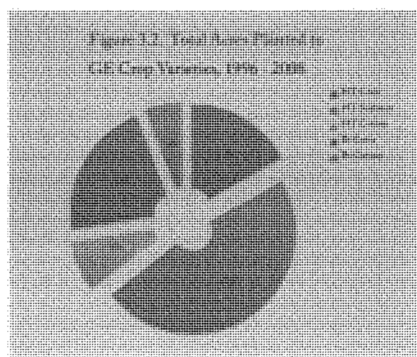


Figure 3.2. Total Acres Planted to GE Crop Varieties, 1996 - 2008

Why would farmers buy corn seed with unnecessary traits? Because such varieties are the only ones available with other valuable genetic traits matched to a particular farm's soils, maturity zone, and production system.

This tendency to under-utilize GE traits is likely to increase markedly in frequency (i.e., the number of fields impacted)

5 Steffey, K., (2007). "*Bt* Corn + Soil Insecticide: What?", *The Bulletin*, University of Illinois Extension, No. 23, Article 4, October 4.

6 Loux, M. (2009). "Weed Control for Liberty Link vs glyphosate-resistant corn," in: C.O.R.N *Newsletter* 2008-04, Ohio State University, http://corn.osu.edu/print.php?issueID=219&PHPSESSID=eae9fe6fe6e2f9a0b5c0d3d06d47f58b.

and scope (the number of superfluous traits in a purchased bag of seed) as the industry offers more multiple-trait varieties and fewer, and eventually no single-trait seeds. The trend away from single-trait corn and cotton varieties and toward multiple-trait, stacked varieties is already well underway, as evident in Monsanto corn trait acreage figures. In its forecast of 2009 trait acres, Monsanto reported:

* No acres planted to corn that expresses ONLY the CRW trait;
* Less than 1 million acres planted to ECB/CRW *Bt* corn **without** the RR trait;
* Less than 1 million acres of dual-trait corn with Roundup Ready/CRW control; and
* 32-33 million acres planted to triple-stack corn containing all three traits (RR/ECB/CRW).[7]

Monsanto introduced a limited supply of the first stacked corn seed in 2000 (enough to plant aronnd 100,000 acres). In 2004 Monsanto released the first stacked RR corn expressing the Cry 3Bb1 gene for CRW control. The first dual-*Bt* corn hit the market in 2005.

The first triple-stack corn hybrid was introduced by Monsanto in 2005. It expressed the two *Bt* genes for ECB/SWCB and CRW control, and was also RR. By 2008, double- and triple-stack corn varieties were planted on 57.3 million acres of corn, compared to just 13.6 million acres planted to single-trait GE corn (the vast majority, 11.8 million acres, RR).[8]

The strategy of offering farmers more multiple-trait stacked varieties and fewer single-trait varieties is referred to in the industry as "biotech trait penetration."[9] This strategy is, in turn, driven by the fee-per-trait pricing structure used across the industry. For instance, Monsanto and Dow AgroSciences recently announced a collaboration to develop so-called "SmartStax" corn hybrids that contain eight GE traits stacked together: six different *Bt* insecticides, three for control of ECB/SWCB and similar above-ground pests, three for control of CRW, and two additional traits for tolerance to the herbicides glyphosate and glufosinate. Analysts note that Monsanto encouraged farmers in 2009 to adopt triple-stack corn in order to "create a captive customer base for the 2010 launch of its SmartStax" corn.[10] Over the next few years Monsanto plans to replace the triple-stack corn hybrids sold in 2009 with the eight-stack hybrids coming on the market in 2010.

The commercial introduction of these varieties raises several new issues and questions, some of which are addressed in Chapter 7.

New Challenges in Tracking GE Traits and Acres

The trend toward stacked traits also raises analytical challenges. In corn and cotton, the total number of GE trait acres now far exceeds the total number of acres planted.

According to the June 24, 2009 Monsanto biotechnology trait acreage report, trait acres forecasted for the 2009 crop season include:

- 39 million acres of ECB *Bt* corn;
- 33 million acres of CRW *Bt* corn; and
- 70 million acres of RR corn.

Accordingly in 2009, a projected 142 million GE trait acres of corn was planted, far more than the 87 million acres of corn grown this year. About 73 million acres of corn were planted to a GE crop variety expressing one or more Monsanto traits. Thus, on the average acre planted to GE corn, the variety expressed 1.9 traits, an already significant degree of "trait penetration."

In the case of cotton in 2009, there were 13.4 million

7 Monsanto (2009). Monsanto Biotechnology Trait Acreage: Fiscal Years 1996-2009F, updated June 24, 2009. Trait figures reported below also from this report.

8 Note that Monsanto's figure of 29.9 million acres for total U.S. single-trait corn acres in the trait acreage report referenced above includes 16.3 million acres that are actually double- or triple-stack corn (i.e. they contain only one Monsanto trait – Roundup Ready – but are stacked with competitors' traits).

9 Monsanto (2006). "Delta and Pine Land Acquisition: Investor Conference Call," Power Point presentation, August 15, 2006, http://www.monsanto.com/pdf/investors/2006/08-15-06.pdf.

10 Goldman Sachs (2008). "Monsanto Company Update: Trait prices going up along with estimates and price target," June 2, 2008, p. 6.

Monsanto-trait acres and 7.7 million acres of GE cotton grown, for an average of 1.7 traits expressed per acre of GE cotton planted.

The tracking of GE seed traits will be complicated by other factors. As the trend toward more multiple-trait varieties continues, seed companies may begin to neither announce, nor charge, for the presence of certain traits, including those that become obsolete (e.g., the RR trait will become obsolete if and when, and wherever the spread of resistant weeds renders the herbicide ineffective).

In other cases, farmers will be forced by lack of choice to buy a variety that contains traits of little or no use. For this reason, future surveys of GE crop traits will need to explore ways to distinguish between total pest management related trait acres and "functional" trait acres, where a given trait actually changes how the farmer manages pests and the crop.

4. Impacts of Herbicide-Tolerant Crops on Herbicide Use

Glyphosate herbicide, marketed as Roundup by Monsanto, has been and remains the backbone of HT cropping systems. The efficacy of RR technology was excellent in the first few years of commercial use. A single application was often all that farmers needed for season long control in corn and soybeans. Typically, an additional application of Roundup or another herbicide was necessary in cotton growing areas, because of the longer growing season and many aggressive weed species in cotton country.

Shifts in weed communities favoring those species not as fully controlled by Roundup started occurring after just a few years of use on the same acre of cropland. After four to six years of applications, such weed shifts to more glyphosate-tolerant species had led to higher rates of Roundup and/or additional applications. In areas where farmers grew RR crops in rotation, like RR soybeans followed by RR cotton, weed populations resistant to Roundup began to emerge and spread.

These changes in weed communities – shifts to more GT species and evolution of glyphosate-resistant biotypes – have driven the incremental increases in both the rates and number of applications of glyphosate and other herbicides required on HT acres.

The title of a recent university extension report to Illinois farmers about the utility of glyphosate-based weed management systems states: "Turn Out the Lights – The Party's Over."[1] In the article, Aaron Hager asserts that:

> "The rapid adoption of glyphosate-resistant corn hybrids and weed spectrum changes in response to near-ubiquitous use of glyphosate in soybean suggests the following theses: *the ability of glyphosate to be a stand-alone herbicide for weed management in soybeans*

1 Hager, A., (2009) "Turn Out the Lights – The Party's Over," *The Bulletin*, University of Illinois Extension, No. 3 Article 4, April 10.

Table 4.1. Changes in the Pounds of Glyphosate Applied per Acre per Crop Year on Corn, Cotton, and Soybeans: 1996-2007

Crop and Period	Glyphosate Rate in 1996	Total Increase (Pounds a.i. per Acre)	Percent Change	Average Annual Percent Change in Period Noted
Corn (1996-2005)	0.68	0.27	39%	4.3%
Cotton (1996-2007)	0.63	1.26	199.8%	18.2%
Soybean (1996-2006)	0.69	0.67	97.6%	9.8%

Note: All use data is from the USDA National Agricultural Statistics Service (NASS) annual surveys of pesticide use, and take into account both changes in the one-time rate of application and the average number of applications per crop year. Corn was last surveyed by NASS in 2005, Cotton in 2007, and Soybeans in 2006.

will (continue to) decline. In other words, the 'simplicity' of glyphosate as a stand-alone weed management tool soon will be relegated to the annals of history." [Emphasis in original]

This ecological adaptation to the RR system was predictable and openly discussed well before the first RR crop was planted. A publication issued in 1990 by the Biotechnology Working Group focused on the impacts of HT crops on sustainable agriculture. It stated nearly 20 years ago that:

"If a shift to herbicide-tolerant crops led to greater use of certain herbicides,... problems associated with resistant weeds would likely increase."[2]

In the 1996 Consumers Union book *Pest Management at the Crossroads (PMAC)*,[3] the "special caution" needed in managing GE crops was highlighted. After discussing the possibility that gene flow could create "super" HT weeds,[4] the report warns that:

"A more widespread concern with herbicide tolerant plants is the likelihood they will accelerate the emergence of resistant weed species...

Glyphosate use on cotton rose from 0.63 pounds in 1996 to 1.89 pounds in 2007, or 18.2% per year as a result of the introduction of RR cotton.

"Gaining the ability to apply the herbicides more frequently or possibly at higher rates is the major reason farmers are willing to pay the higher cost for transgenic seed. ***Such changes in the pattern of herbicide use, though, are almost custom-made for accelerating resistance.***" (page 220, emphasis added)

The impact of shifts to weed species more tolerant of glyphosate and the evolution and spread of GR populations is unmistakable in USDA pesticide use data over the last 13 years. Table 4.1 summarizes the changes in glyphosate application rates per crop year for corn, soybeans, and cotton that have occurred since 1996, before the widespread planting of HT varieties. Supplemental Table 16 is the source of Table 4.1, and reports full details on glyphosate rates for the three crops.

The first column in Table 4.1 presents the glyphosate application rate per crop year in 1996 and the next column reports the increase from 1996 through the most recent NASS survey (2005 for corn; 2006 for soybeans; 2007 for cotton). The increases take into account both changes in the one-time rate of application, as well as the average number of applications made in a crop season. The third column reports the overall percentage increase and the last column shows the average annual percentage increase in glyphosate rates per crop year.

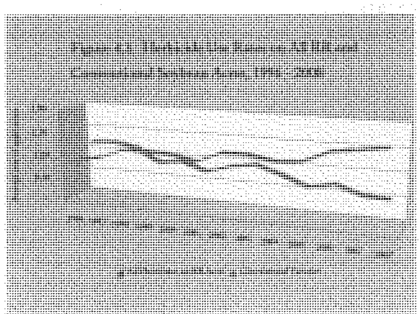
2 Goldburg, R., Rissler, J., Shand, H., and Hassebrook, C. (1990). "Biotechnology's Bitter Harvest: Herbicide-Tolerant Crops and the Threat to Sustainable Agriculture," A Report of the Biotechnology Working Group.

3 Benbrook, C. et al., (1996). *Pest Management at the Crossroads*, Consumers Union.

4 Herbicide-tolerant gene flow is a process whereby a resistance gene engineered into a HT crop moves (usually via pollen flow) to a weed species that is genetically related to a GE plant and capable of cross-fertilization with the GE plant.

In cotton, the average rate of glyphosate rose from 0.63 pounds in 1996 to 1.89 pounds in 2007 — clearly good news for the manufacturers of glyphosate herbicides, but bad news for farmers and the environment. Most of this increase was driven by the need to make additional Roundup applications. One application of glyphosate brought about adequate control in 1996 on most cotton farms. Just two years later, 1.5 applications were necessary. By 2003, an average of two applications were made, and by 2007, 2.4 applications. During this time period, the average one-time rate of application went up by 25%, from 0.63 to 0.79 pounds per cotton acre. Glyphosate use on cotton per crop year rose 18.2% per year from 1996 to 2007 as a result of the introduction of RR cotton.

Roundup is a relatively high-dose herbicide. It is applied at around three-quarters of a pound of AI per acre, compared to many other cotton herbicides applied at rates below 0.1 of a pound.[5] The need to make 2.4 applicarions of glyphosate to control weeds in HT cotton fields in 2007, compared to the just one in 1996, is obviously going to drive up total herbicide use, especially compared to fields planted to conventional cotton, where very low-dose herbicides are among the market leaders.[6]



5 NASS data show that there are a half-dozen cotton herbicides applied at rates below 0.01 pound per acre of active ingredient, and another three applied at rates between 0.01 and 0.1 pound per acre.

6 The cotton herbicide pyrithiobac-sodium was applied to 10% of cotton acres in 2007 at the rate of 0.052 pounds per acre; pyraflufen-ethyl was applied to 8% of acres at 0.003 pounds per acre.

The soybean glyphosate rate per crop year increased from 0.69 pounds per acre in 1996 to 1.36 pounds in 2006, or 9.8% per year. The average one-time rate of application rose 27% from 1996 through 2006, while the number of applications rose from 1.1 to 1.7, or 55%.

In corn, the pounds of glyphosate applied rose "only" 4.3% per year. The reason is clear -- RR corn was adopted much more slowly than HT cotton and soybeans. Market penetration did not reach a third of national corn acres until 2006. Accordingly, corn farmers are just now entering the time period when substantial increases are likely in glyphosate application rates, unless farmers switch to other herbicides and weed management technology.

A. Herbicide-Tolerant Soybeans

The general procedure for estimating herbicide use on conventional and GE acres was described in the methodology section in Chapter 2. Here, the methodology is briefly summarized and issues specific to each crop are discussed.

The average number of pounds of herbicides applied to HT acres is composed of the volume of Roundup applied plus an estimate of the pounds of other herbicides needed to achieve effective control.

Total herbicide applications on acres planted to conventional seeds is calculated by use of a weighted-average formula computing the average pounds of herbicides applied on all acres from the pounds applied on conventional and GE acres, coupled with the shares of acres planted to HT and conventional varieties.

The average pounds applied on acres planted to conventional seeds is then subtracted from the average pounds applied to HT acres, producing the difference in herbicide use on an acre of HT crop, in contrast to acres planted to conventional varieties.

Herbicide use rates on all soybean acres, HT acres, and conventional acres are computed in Supplemental Table 15 and are displayed graphically in Figure 4.1.

The values in the line "Glyphosate on RR Acres" in Supplemental Table 15 are directly from NASS reports. A small portion of glyphosate applications are made preplant or at planting time to kill weeds that have germinated.

Some of these acres might be planted to conventional varieties. Still, the average rate of glyphosate application does not differ markedly between a preplant and postemergence application over the top of most RR crops.

Total herbicide and glyphosate application rates per crop year were projected to increase 5% from 2006 to 2007, and 5% again from 2007 and 2008. These rates of increase are one-half the 9.8% annual rate of increase in the glyphosate use per crop year from 1996 through 2006 (last column, Table 4.1). This assumption is conservative (understates glyphosate use), especially in light of the continuing emergence of weeds less susceptible or resistant to glyphosate.

The variable "Other Herbicides on RR Acres" in Supplemental Table 15 is estimated from NASS data taking into account changes from year to year in overall herbicide use, changes in the glyphosate rate per acre, an upsurge in use of non-glyphosate herbicides to control resistant weeds, and recent trends in the rate of herbicides applied to conventional acres.

Despite the growing trend to utilize more non-glyphosate herbicides on RR soybean, the amount of such herbicides applied on RR soybean acreage has trended downward, reflecting the shift toward low and very low-dose herbicides. For instance, NASS reports 17 herbicides that were applied on soybean acres in 2006 with application rates below 0.1 pound per acre. Dozens of combinations of two or three of these herbicides could be applied without exceeding a total of 0.15 pounds of active ingredient applied per acre.

The Supplemental Table 15 line "All Herbicides on RR Acres" is simply the sum of glyphosate and other herbicides applied per acre of HT soybeans. The weighted average formula is then used to calculate the rate per acre for "Conventional Varieties." This value drops gradually from 1.19 pounds per acre in 1996 to 0.49 pounds in 2008, again reflecting the transition toward heavier reliance on low-dose soybean herbicides.

In the first two years of commercial adoption, RR technology reduced herbicide use by 0.3 and 0.23 pounds per acre, as shown in the last line in Supplemental Table 15. But by 1998, the rate of glyphosate per crop year had increased enough to push the average rate on HT acres above the conventional crop rate by 0.07 pounds. A high level of confidence can be placed on this estimate for 1998 because of a special analysis carried out by the USDA's ERS (described below).

From 1998 on, the difference between average herbicide applications rates per crop year on RR soybean acres compared to conventional acres gradually rises over the next 10 years, reaching 1.16 pounds per acre by 2008. The increase in this differential is driven in large part by the 9.8% annual increase in glyphosate use per acre. The most dramatic increases in glyphosate use came between crop years 2001 and 2002, and 2005 and 2006, when the glyphosate rate per crop year rose about 20% in a single year.

Special ERS Tabulation in 1998

The ERS carried out a series of special tabulations of herbicide use data on HT and conventional soybean acres drawing on crop sample points in the 1998 Agricultural Resource Management Survey (ARMS). This tabulation was requested and paid for by Benbrook Consulting Services. In this tabulation, ERS analysts divided all soybean acres into four categories:

* Conventional varieties, no glyphosate applied;
* Conventional varieties, glyphosate applied (mostly on no-till acreage);
* RR varieties; and
* Other HT varieties.

From the ARMS soybean dataset, ERS calculated both the percent of total soybean acreage by category, as well as the average number of herbicides and pounds of herbicides applied in each category. This information was used to calculate total herbicide use per acre on conventional and HT soybeans in 1998, using the weighted average formula described previously, as shown in Table 4.2.

The rates and percents of acres planted to conventional varieties treated and not treated with glyphosate were used to calculate

Table 4.2. Difference in Herbicide Application Rates per Acre on Herbicide-Tolerant (HT) Versus Conventional Soybeans in 1998, Based on a Special Tabulation of ARMS Data, Carried Out by the ERS

	Percentage Acres Treated	Acres Planted	Average Number Herbicides Applied per Acre	Average Pounds Herbicides Applied per Acre
Conventional Varieties, No Glyphosate Applied	47.9%	34,470,555	2.7	1.08
Conventional Varieties, Glyphosate Applied	8.0%	5,733,953	3.3	1.45
Total Conventional Varieties		40,204,508		
RR Varieties	38.8%	27,928,106	1.4	1.22
Total HT Varieties	5.4%	[illegible]	2.8	1.06
All Soybeans	100%	72,025,000		
Weighted Average Rate on Conventional Acres	1.13			
Weighted Average Rate on HT Acres	1.20			
Difference Between Conventional and HT Varieties	0.07			

Source: Percent acres treated, number of applications and pounds applied per acre by type of seed are from special tabulations done by the Economic Research Service for Benbrook Consulting Services. Calculations of rates of application on conventional and HT methods by Benbrook Consulting Services.

the overall conventional soybean rate of 1.13 pounds per acre. Conventional acres treated with glyphosate were planted using either no-till or conservation tillage systems in which the glyphosate is applied before soybean seeds germinate.

The average rate of all herbicides applied on HT acres was calculated at 1.2 pounds per acre. Accordingly, the average acre of HT soybeans in 1998 required 0.07 pounds more herbicide than the average acre of conventional soybeans.

B. Herbicide-Tolerant Corn

Adoption of HT corn increased more slowly than HT soybeans and cotton, in large part because of several cost-effective, herbicide-based weed management alternatives. By 2001, 68% of soybeans and 74% of cotton acres were planted to HT varieties, whereas just 8% of corn acres were planted to HT seeds.

Farmers were slower to adopt the higher cost HT corn varieties because, in general, corn weed management is simpler than soybean or cotton weed management. Corn germinates and grows quickly, producing a "closed canopy" earlier in the crop season than in soybean and cotton fields. A crop has a "closed canopy" when the foliage of the crop fully shades the ground from direct sunlight. Weed germination and growth slow dramatically once a crop canopy is closed.

As in the case of soybeans, projections of herbicide use on HT corn acres are based on the performance of the RR system. NASS data on corn herbicide use suggest that between 2% and 5% of corn acres in some years were treated with glufosinate, the active ingredient associated with HT LibertyLink corn varieties. An unknown portion of these corn acres was planted to HT varieties. On these glufosinate HT acres, the average rate of herbicide use was likely somewhat lower than on the average RR acre, because glufosinate is applied at about one-half the glyphosate rate. Still, LibertyLink acres have had a very modest impact on overall HT corn herbicide use.

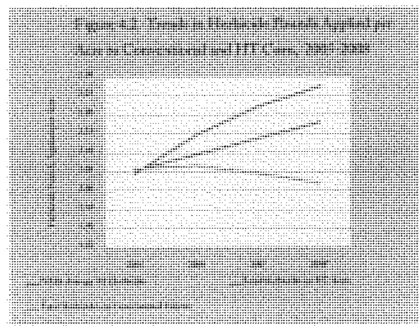
On HT acres, the rate of glyphosate per crop year is taken directly from NASS data, or extrapolated from NASS data since 2005, as shown in Supplemental Table 13. NASS surveyed corn acres in 2003 and 2005, the period during which the percent of corn acres planted to HT varieties rose from 15% to 26%. In this period, the rate of glyphosate applied per crop year rose on average 7.1% per year. Accordingly, and to be conservative, increases of 5% in the glyphosate rate per crop year and were assumed to occur in 2006, 2007, and 2008.

The volume of herbicides other than glyphosate applied to HT corn acres was estimated from university weed management recommendations. The volume of "Other Herbicides on HT Acres" decreased modestly from 1.2 pounds per acre in 1996-1997 to 1.1 in 2005. The volume applied then increases about 7% over three years to 1.18 pounds in 2008 as a result of changes in weed communities and the growing presence of resistant weeds.

From 1996 through 2008, total herbicide use on HT corn acres rose from 1.88 pounds of active ingredient to 2.27, a 21% increase. During this period, glyphosate use is projected to increase from 0.68 pounds per acre to 1.09 pounds, a 60% increase (five percent per year).

Total herbicide applications on conventional and other non-HT[7] corn acres trended downward from 1996 through 2008, falling from 2.67 to 2.02 pounds per acre, reflecting the gradual shift to lower-dose herbicides, as well as regulatory limits on the rate of atrazine that can be applied. The registration of s-metolachlor also contributed to a reduction in average corn herbicide application rates.

[7] Note that single trait *Bt* corn without herbicide tolerance is treated as "conventional" for the purposes of this HT corn discussion.



This product is a more active stereoisomer of metolachlor, and is effective at an application rate about 35% below metolachlor's typical rate of applicarion.

Overall, herbicide use per acre on all corn acres also trended downward during this period from 2.65 pounds in 1996 to 1.9 pounds in 2002. Herbicide use per acre then began rising, from 1.9 pounds in 2002 to 2.05 pounds in 2005, the last year NASS surveyed corn pesticide use. During this three-year period, average use per acre rose 2.7% annually. From 2005 through 2008, total herbicide use was projected to increase 2% per year. Herbicide use per crop year for all corn, HT, and conventional corn varieties is shown in Figure 4.2., covering the full thirteen year period. The difference in total herbicide use on HT corn acres, compared to conventional corn acres, gradually changes from a reduction of 0.79 pounds per acre in 1996 to an increase of 0.25 pounds per acre in 2008. This shift from a significant reduction per acre of HT corn to a moderate increase in herbicide use is driven by a combination of factors:

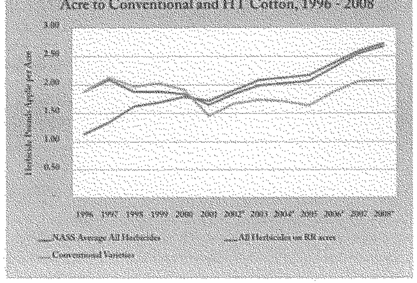
* Increased average annual glyphosate use rates on HT acres;
* An approximate 30% increase in the average number of applications; and
* Steady reductions in the average pounds of herbicides applied on conventional corn acres.

C. Herbicide-Tolerant Cotton

Of the three crops covered in this report, cotton farmers face the most difficult challenge in managing weeds. The space between cotton rows is greater than in corn and soybeans fields. The canopy closes more slowly in cotton fields, and sometimes never fully closes. The cotton growing season is longer than corn and soybeans, giving weeds an extended window of opportunity to germinate and grow. This requires conventional farmers to make more applications of generally longer-acting herbicides.

In the case of cotton, NASS pesticide use data are available through crop year 2007, as shown in Supplemental Table 14. Total herbicide use on all cotton acres rose from 1.88 pounds of active ingredient in 1996 to 2.55 in 2007, or 35% (a modest 3.2% per year). The rate of increase shot up dramatically between 2005 and 2007. Total herbicide use per acre rose 11.6% annually in this period.

Figure 4.3. Trends in Herbicide Pounds Applied per Acre to Conventional and HT Cotton, 1996 - 2008



The increase in glyphosate use per crop year was sizable from 2005 to 2007 – 0.32 more pounds per acre, or an annual 10.2% increase. Between 2007 and 2008, the increase in glyphosate use is conservatively estimated to rise by just 7%, and the total pounds of herbicides applied per acre is projected to increase less sharply, at a rate of 5% (compared to 11.6% annually from 2005-2007). Figure 4.3 displays these trends in cotton herbicide use graphically.

On conventional cotton acres, total herbicide use declined in most years between 1996 and 2001, but has increased steadily since that time, reaching 2.07 pounds per acre in 2008. The increase in the total pounds of herbicides used on conventional cotton acres is driven in large part by shifts in weed communities and the emergence of weeds that are tolerant or resistant to various herbicides. Tough-to-control weeds in the cotton belt that have emerged as a result of heavy reliance on RR technology include horseweed (also called marestail), Johnsongrass, and pigweed (Palmer amaranth).

During the first five years of use, HT upland cotton reduced the total volume of herbicides used per acre, an outcome brought about by the high degree of efficacy of glyphosate in the early years of HT crops. By crop year 2001, each acre of HT cotton required more herbicide than the average conventional cotton acre. The margin of difference rose incrementally over the next decade, reaching 0.65 pounds per acre in 2008.

D. Impacts of Resistant Weeds on Herbicide Use and Risks

The Weed Science Society of America (WSSA) and the industry-sponsored Herbicide Resistance Action Committee maintain a registry of resistant weed species around the world (accessible at www.weedscience.org). The WSSA defines weed resistance as "the inherited ability of a plant to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type."

Scientists use a simple test to screen for levels of resistance. The amount of herbicide required to reduce plant growth by 50% is measured, producing a value called the GR50, for "Growth Reduction by 50%." A case of resistance is regarded as clear cut when the GR50 herbicide dose in a weed population is at least 10-fold higher than the GR50 in a susceptible weed population.

Widespread use of HT technology has turned the U.S. into the resistant weed epicenter of the world. The WSSA records 125 resistant biotypes of 68 weeds, infesting up to 18 million acres in the U.S., while Australia is a distant second with 53 resistant biotypes.

The actual number of resistant weed populations and the acreage infested with them are likely higher, since the WSSA system is a passive reporting system that depends on academic

Table 4.3. Estimates of Acres Infested with Glyphosate Resistant Weeds in 2008, by Type of Weed

Common Names	Species	Maximum Acres	Crops Infested
Common Ragweed	*Ambrosia artemisiifolia*	150	Soybeans
Common Waterhemp	*Amaranthus rudis*	10,700	Corn, Soybeans
Giant Ragweed	*Amobrosia trifida*	12,550	Cotton, Soybeans
Hairy Fleabane	*Conyza bonariensis*	Unknown	Roadsides
Horseweed (Marestail)	*Conyza canadensis*	3,333,210	Corn, Cotton, Rice, Soybeans, Roadsides, Nurseries
Italian Ryegrass	*Lolium multiflorum*	10,005	Cotton, Soybeans, Orchards
Johnsongrass	*Sorghum halepense*	Unknown	Soybeans
Palmer Amaranth	*Amaranthus palmeri*	2,000,500	Corn, Cotton, Soybeans
Rigid Ryegrass	*Lolium rigidum*	10,000	Almonds
Source: Weed Science Society of America survey of resistant weeds, www.weedscience.org			

weed scientists to upload their data on resistant populations. WSSA also has strict standards that must be met for verifying resistance before a resistant weed report is listed, which in some cases may delay or prevent likely cases from being reported.

In addition, WSSA does not report cases of ecological weed shifts – the selection and increasing predominance of weed species that are naturally more tolerant of an intensively used herbicide. For instance, a number of GT weed species are becoming more prominent in GR cropping systems, including common lambsquarters, velvetleaf, Asiatic dayflower and tropical spiderwort, among others.[8] Some weed scientists have called for more active and intensive surveillance of resistant weeds in HT cropping systems.[9]

Dramatic Increases Reported in Glyphosate Resistance

Glyphosate was first introduced in 1974, and for the next 22 years there were no confirmed reports of GR weeds. A few isolated populations of resistant weeds – mainly rigid and Italian ryegrass and goosegrass – emerged in the late 1990s, attributable to intensive glyphosate use in orchards (e.g., Malaysia, Chile, and California) or in wheat production (Australia). The vast majority of GR weed populations have emerged in RR cropping systems since the year 2000. Today, the WSSA website confirms that populations of 16 weed species are resistant to glyphosate in one or more countries, and of these, biotypes of eight species are also resistant to herbicides in one or two other families of chemistry.[10]

The first GR weed population confirmed in the U.S., reported in 1998, was rigid ryegrass, infesting several thousand acres in California almond orchards. Beginning in the year 2000 in Delaware, GR marestail (horseweed) rapidly emerged in RR soybeans and cotton in the East and South. Less than a decade later, GR biotypes of nine species are now found in the U.S., and infest millions of acres of cropland in at least 22 states (see Table 4.3).

The emergence of glyphosate resistance has accelerated in recent years. As of November 2007, the WSSA system recorded eight weed species resistant to glyphosate, covering

8 Owen, M. D. K., (2008). "Weed species shifts in glyphosate-resistant crops," *Pest Manag Sci* 64: 377-387. Owen also cites reports of truly glyphosate-resistant lambsquarters, which however are not listed by WSSA.

9 GAO (2008). "Genetically engineered crops: Agencies are proposing changes to improve oversight, but could take additional steps to enhance coordination and monitoring," Report to the Committee on Agriculture, Nutrition, and Forestry, U.S. Senate, U.S. Government Accountability Office, GAO 09-060, Nov. 2008, pp. 30-31.

10 See http://www.weedscience.org/Summary/UspeciesMOA.asp?lstMOAID=12&FmHRACGroup=Go, last visited Nov. 3, 2009.

up to 3,200 sites on up to 2.4 million acres. By early 2009, as many as 14,000 sites on up to 5.4 million acres were documented to be infested by populations of nine glyphosate-resistant weeds. This represents more than a four-fold increase in the number of sites, and roughly a doubling of acreage, plagued by resistant weeds.[11]

Most resistant weed populations thus far have been driven by intensive glyphosate use associated with RR soybeans and RR cotton, which are often rotated. However, adoption of corn with the RR trait has increased sharply in recent years, from 20% to over 60% of national corn acres from just 2004 to 2008. The increasing reliance on glyphosate associated with the growing use of RR soybean/RR corn rotations is likely responsible for the rapid emergence of resistant weeds in the Midwest and Northern Plain states. This troubling trend can only accelerate in the future, absent serious resistant weed management programs.

The emergence and rapid spread of GR weeds has driven rising herbicide use in all three HT crops, especially in recent years. Increasing glyphosate application rates and/or the number of applications will usually buy a little time, but invariably accelerates the emergence of full-blown resistance. This is the classic definition, and regrettable outcome, of what scientists call the "pesticide treadmill."

Below, we present case studies of three particularly troubling GR weeds: Palmer amaranth (pigweed), horseweed, and giant ragweed.

The "Perfect Weed"

GR Palmer amaranth has been called "the perfect weed." It has spread rapidly across the southern U.S. in the wake of RR cotton, soybeans, and more recently, corn.

By November 2007, WSSC had recorded GR Palmer amaranth on four to seven sites encompassing up to 1,000 acres in three states. Less than two years later, resistant biotypes had been confirmed by WSSC on up to 500 sites in seven states, covering an estimated two million acres.

The first confirmation of GR Palmer amaranth came in 2004 in just one county in Georgia. It spread quickly and reached nine additional counties in 2006, 10 more in 2007, and at least another nine in 2008.[12] Estimates of Georgia cotton and soybean acreage infested with GR Palmer amaranth rose from 500 acres in 2005 to as many as one million acres in 2009.[13]

In Tennessee, GR Palmer amaranth was first reported in 2006 on two to five sites covering up to 500 acres. By 2008, hundreds of fields in 10 Tennessee counties were infested.[14]

A similar pattern is unfolding in North and South Carolina, Arkansas, Alabama and Mississippi. For instance, up to one million acres are infested in North Carolina,[15] and another 130,000 acres are infested in South Carolina.[16] Auburn University weed scientist Mike Patterson predicts that GR

11 For analysis of the WSSA data, see Center for Food Safety's Comments to USDA's Animal and Plant Health Inspection Service re: Proposed Rules for the Importation, Interstate Movement, and Release into the Environment of Certain Genetically Engineered Organisms, APHIS Docket No. 2008-0023, June 29, 2009, Addendum 1, at: http://truefoodnow.files.wordpress.com/2009/06/final-comments_june29_aphis-2008-0023_final.pdf.

12 Culpepper and Kichler (2009). "University of Georgia Programs for Controlling Glyphosate-Resistant Palmer Amaranth in 2009 Cotton," University of Georgia Cooperative Extension, April.

13 http://www.weedscience.org/Case/Case.asp?ResistID=5256.

14 Robinson, E., (2009). "Pollen big factor in resistant pigweed spread," *Southeast Farm Press*, http://southeastfarmpress.com/cotton/herbicide-resistance-0428/ April 28, 2009.

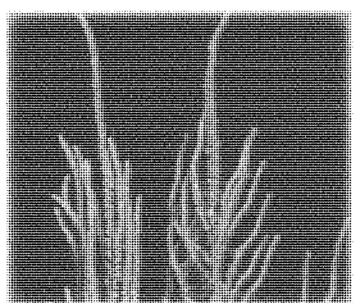
15 http://www.weedscience.org/Case/Case.asp?ResistID=5360, a 2005 report that first appeared on WSSC-HRAC website in 2009.

16 Robinson, E. (2008b). "Designing the perfect weed - Palmer amaranth," *Delta Farm Press*, http://deltafarmpress.com/cotton/palmer-amaranth-1226/ December 24.

Palmer amaranth will spread across southern Alabama fields in the coming years.[17]

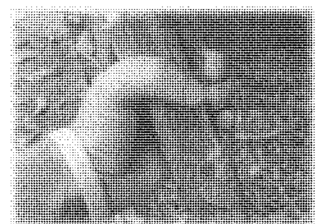
Both farmers and weed scientists fear the spread of GR Palmer amaranth for good reason. GR Palmer amaranth is aggressively invasive, as demonstrated by its explosive rate of spread. It has significant negative impacts on farm and harvest operations and is extremely difficult to control. The mature weed often grows to over six feet in height. Its sturdy stalk can reach six to eight inches wide at its base[18] and has damaged harvest equipment, including cotton pickers.[19]

GR Palmer amaranth infestations can trigger abandonment of cropland. Some 10,000 acres of cotton in Georgia in 2007 were abandoned because of the presence of GR Palmer amaranth,[20] examples of farm fields pushed over the "cliff" by resistant weeds.



Just two Palmer amaranth plants along a 20 feet section of a row of cotton can reduce yields by almost one-quarter, imposing on farmers a devastating economic loss. A single female plant can produce up 450,000 seeds.

Scientists in Arkansas and Tennessee believe that GR Palmer amaranth seed is spread via flooding, the movement of farm machinery, and the wind.[21] However, long-distance pollen flow is probably the most significant mode of propagation. In one experiment, a glyphosate-susceptible female plant was partially inoculated by a single resistant male plant that was 300 meters away. Some 20% of the resulting progeny were glyphosate resistant.[22]



Initially in Tennessee, some GR Palmer amaranth populations could survive 44 ounces of Roundup, more than twice the amount of Roundup a farmer would typically apply. By 2008 some populations of GR Palmer amaranth could withstand up to seven times the typical rate of glyphosate application. In some Palmer amaranth biotypes, the weed has attained a higher level of resistance to glyphosate than the RR crops planted in the field.[23]

Glyphosate resistance in this prolific weed is bound to increase weed management costs and the average pounds of herbicides applied per acre, regardless of whether farmers continue to plant RR crops. A weed scientist at the University of Tennessee estimated that on average GR Palmer amaranth would cost cotton growers in the South an extra $40 or more per acre in weed management costs in 2006,[24] a major increase given that expenditures on all

17 Hollis, P. L., (2009). "Resistant pigweed control programs updated," *Southeast Farm Press*, http://southeastfarmpress.com/cotton/weed-resistance-0519/ May 19.

18 Roberson, R., (2008). "Herbicide-resistant weed problems spreading," *Southeast Farm Press*, May 14.

19 Minor, E., (2006). "Herbicide-resistant weed worries farmers," *Associated Press*, 12/18/06, available at http://www.enn.com/top_stories/article/5679, Dec. 18. (last visited Sept. 9, 2007).

20 Robinson, E., (2008b), op. cit.

21 Bennett, D. (2008), op. cit. "Resistant pigweed 'blowing up' in Mid-South," *Delta Farm Press*, http://deltafarmpress.com/cotton/resistant-pigweed-0730/ July 30.

22 Robinson, E., (2008a), op. cit.

23 Robinson, E., (2008a), op. cit., emphasis added.

24 Laws, F., (2006). "Glyphosate-resistant weeds more burden to growers' pocketbooks," *Delta Farm Press*, http://deltafarmpress.com/news/061127-glyphosate-weeds/ November 27.

cotton pesticides averaged around $60 per acre in 2005.[25]

Making matters worse for farmers, there are few economical options for dealing with GR Palmer amaranth after it reaches six inches in height, in part because so many populations of Palmer amaranth are already resistant to other herbicides, including the ALS inhibitors. The only effective herbicides that remain on the market are PPO inhibitors. These herbicides inhibit the protoporphyrinogen oxidase (PPO) enzyme in the pigment synthesis pathway. Inhibition of this enzyme starts a reaction in plant cells that causes cell membranes to leak. The leaking cell membranes rapidly dry and disintegrate.

Preserving the efficacy of this last line of defense is now a priority for weed scientists in the region. One scientist asserts that an effective resistance management plan for the PPOs is all that stands between GR Palmer amaranth and "***...the ability to do economic weed control in cotton and soybeans.***"[26]

Glyposate-Resistant Horseweed

Horseweed, or marestail, is a second "high impact" GR weed that has spread rapidly over the past two years. First documented in the year 2000 in Delaware, GR horseweed now infests up to 3.3 million acres across tens of thousands of sites in 16 states. In just the State of Illinois, up to 10,000 sites and as many as one million acres are infested.[27] Over two million acres were reported as infested in 2001 in Tennessee.[28] GR horseweed in Mississippi is also resistant to paraquat,[29] the first time multiple resistance to these two herbicides has been documented.

Weed scientists regard GR horseweed as a "worst-case scenario" in RR cropping systems because this weed is well adapted to no-tillage planting systems popular among GR crop growers. It also producers up to 200,000 seeds per plant, and its seeds can disperse extremely long distances in the wind.[30]

GR horseweed is high impact in part because it can reduce cotton yields by 40 to 70%.[31] An Arkansas weed scientist estimated that Arkansas growers would have to spend as much as $9 million to combat GR horseweed in 2004.[32] An uncontrolled outbreak of GR horseweed in Arkansas could reduce the income of cotton and soybean farmers by nearly $500 million, based on projected loss in yield of 50% in 900,000 acres of cotton and a 25% yield loss in the over three million acres of soybeans.[33]

The situation is even more precarious in Tennessee, where nearly all cotton acres are now infested with GR horseweed. In 2004, ten plants per square foot[34] were considered a heavy GR horseweed population. By 2007, the "heavy" infestation threshold has risen to 20 to 25 plants per square foot. In most of the Southeast, GR horseweed is now forcing farmers to rely more heavily on mechanical tillage for weed control, in the process reducing substantially the

25 USDA ERS (2007b). Cost and return data for cotton production: 1997-2005. USDA Economic Research Service, http://www.ers.usda.gov/data/CostsandReturns/data/recent/Cott/R-USCott.xls. last accessed January 12, 2007.

26 Robinson, E. (2008b), op. cit.

27 See http://www.weedscience.org/Case/Case.asp?ResistID=5276.

28 http://www.weedscience.org/Case/Case.asp?ResistID=5122.

29 http://www.weedscience.org/Case/Case.asp?ResistID=5384.

30 Owen, M. D. K. (2008). "Weed species shifts in glyphosate-resistant crops," *Pest Manag Sci* 64: 377-387.

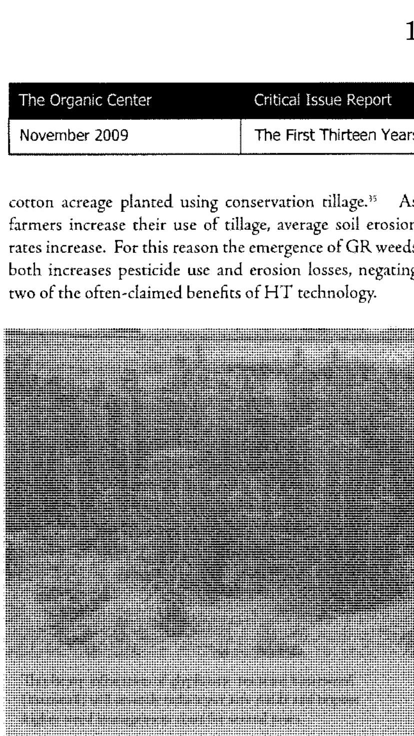
31 Laws, F. (2006), op. cit.

32 AP (2003). "Weed could cost farmers millions to fight," Associated Press, http://www.biotech-info.net/millions_to_fight.html, June 4.

33 James, L. (2005). "Resistant weeds could be costly," *Delta Farm Press*, http://deltafarmpress.com/news/050721-resistant-weed/, July 21, 2005.

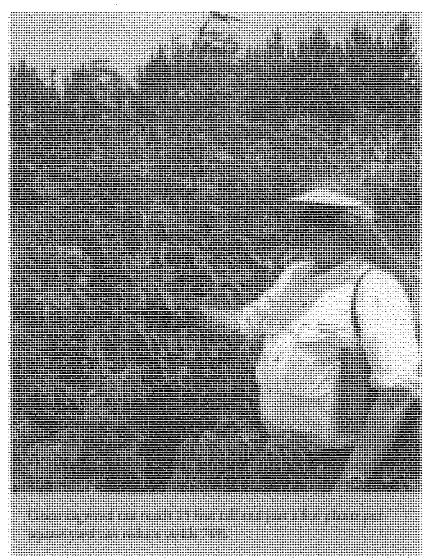
34 Robinson, E. (2008c). "Weed control growing much more complex, new tools coming," *Delta Farm Press*, March 27.

cotton acreage planted using conservation tillage.[35] As farmers increase their use of tillage, average soil erosion rates increase. For this reason the emergence of GR weeds both increases pesticide use and erosion losses, negating two of the often-claimed benefits of HT technology.



Glyphosate-Resistant Giant Ragweed

Six states now have confirmed populations of GR giant ragweed: Ohio, Arkansas, Indiana, Minnesota, Kansas and Tennessee. In December 2006, Purdue University extension agents confirmed the first population of GR giant ragweed in Indiana.[36] Eighteen months later, GR giant ragweed had spread into 14 counties in Indiana and populations, with dual-resistance to glyphosate and ALS inhibitors reported in some populations.[37] Ohio State University researchers have identified giant ragweed with relatively high levels of resistance to both PPO and ALS inhibitor herbicides in three counties, and populations with lower levels of dual resistance in four other counties. They warn that although these weeds can be managed with glyphosate,"continuous use of this practice is likely to result in resistance to glyphosate as well."[38]



Giant ragweed is considered the most competitive broadleaf weed in Indiana soybean production. It can grow up to 15 feet tall. Three to four giant ragweed plants per square yard can reduce crop yields by as much as 70%.

As new populations of resistant weeds emerge, and today's resistant weeds spread, the presence in any given field of weeds

35 Steckel, L., Culpepper S., and Smith K., (2006). "The Impact of Glyphosate-Resistant Horseweed and Pigweed on Cotton Weed Management and Costs," Power Point presentation at Cotton Incorporated's "Crop Management Seminar," Memphis, http://www.cottoninc.com/CropManagementSeminar2006/SeminarProceedings/images/Steckle%20Larry.pdf; Laws, F. (2006), op. cit.

36 Johnson, B., and Loux, M. (2006). "Glyphosate-resistant giant ragweed confirmed in Indiana, Ohio," Purdue University press release, December 21.

37 Johnson, B., and Nice, J., (2008). "Lots of weedy soybean fields," Purdue Extension Weed Science, July.

38 Loux, M., and Stachler, J., (2008). "Giant ragweed with resistance to PPO and ALS inhibiting herbicides," Crop Observation and Recommendation Network Newsletter 2008-11, 4/29 to 5/6/08.

resistant to herbicides in multiple families of chemistry will become commonplace. This will compel farmers to rely more heavily on tillage and herbicides, including many older ones such as 2,4-D, that work through still effective modes of action.

HT Crops Accelerate the Pesticide Treadmill

Farmers have been creating, and then dealing with HR weeds since the use of herbicides became prevalent in the 1970s. As discussed in Chapter 2 , weeds resistant to triazine and later ALS-inhibitor herbicides (among others) emerged well before the introduction of GE HT crops in the mid 1990s (see also Figure 2.4). This fact has led some, notably the biotechnology and seed industries, to assert that there is nothing new or different with GR weeds. In fact, the causes and consequences of the emergence of GR weeds are different in many ways.

HT crop technology allows herbicides (in this case, glyphosate) to be applied in ways and at times not previously possible. Crops can be sprayed over an extended period of time, instead of during one optimal application window. This leads to multiple applications of the same herbicide in the same season. The rotation of one RR crop following another creates near-continuous selection pressure on weed populations over two or more years. Higher rates of application can be made, increasing the volume sprayed.

The sheer scope of introduction of GR crops has fostered such unprecedented reliance on a single chemical for weed control that one leading one expert has remarked that "Glyphosate is as important to world agriculture as penicillin is to human health."[39] This extreme reliance makes the threat of GR weeds far more menacing than herbicide-resisrant weeds of the past. As discussed in Chapter 7, the responses to this threat proposed thus far will likely make matters worse.

Already in some regions, only one herbicide mode of action remains effective and available to manage resistant weeds. Ramping up use of herbicides in still-effective families of chemistry will buy farmers and industry some time, but it will also bring on more resistant weeds. Unless steps are taken to break the underlying ecological conditions favoring the selection and spread of resistant weeds, this vicious circle will grind through the list of registered herbicide products until there are no longer any economically viable herbicide-based options.

No one can predict with confidence when such a breaking point fot herbicide-based weed management systems will occur for a given crop and region. Attempts to deal with resistant weeds through development of GE crops tolerant to a longer list of herbicides and more overall use of herbicides will almost certainly shorten the path to such breaking points.

Failure to act on the lessons learned in regions heavily reliant on HT crop technology that are now infested with two or more difficult to control weeds resistant to multiple herbicides will virtually guarantee that the tipping point will come sooner rather than later, and when it arrives, farmers will be forced to make systemic changes in farming systems that will be costly in multiple dimensions.

39 Stephen Powles, director of the Western Australian Herbicide Resistance Initiative, as quoted in Service, R.F. (2007). "A Growing Threat Down on the Farm," *Science* 316: 1114-17.

5. Impacts of *Bt* Crops on Insecticide Use

Bt corn and cotton have been modified to express a synthetic, truncated version of a natural bacterial toxin, as explained in Chapter 2. These crystalline compounds are produced by several subspecies of the bacterium *Bacillus thuringiensis*. GE corn and cotton have been developed expressing a variety of different *Bt* toxins, each with a unique spectrum of insect control activity.

Two types of *Bt* corn have been sold since 1997. The original *Bt* corn hybrids, expressing the Cry1Ab toxin, helped farmers control the European corn borer and the Southwestern corn borer (ECB/SWCB). In 2003, Monsanto introduced a new type of *Bt* corn that produces Cry3Bb1, a toxin active against the corn rootworm (CRW) and some other soil-borne insects. In 2005, Dow and Pioneer obtained approval to introduce *Bt* corn expressing the Cry34Ab1/Cry35Ab1 toxins, also active against CRW. These pests damage young corn plants by feeding on their roots and have historically been a much greater economic problem for farmers than the ECB/SWCB.

Cotton plants have also been genetically engineered to express different forms of *Bt*. Monsanto's original Bollgard cotton, expressing the Cry1Ac toxin, was introduced in 1996. The Bollgard trait, stacked with the RR trait, accounted for the majority of *Bt* cotton acres through 2006.

Bollgard II cotton, introduced by Monsanto in 2003, expresses two toxins – Cry1Ac and Cry2Ab2. Bollgard II cotton is gradually displacing its predecessor, and accounted for one-half of *Bt*-cotton acres in 2007 and about two-thirds in 2008. Both the original Bollgard and Bollgard II traits target the budworm-bollworm complex of insect pests, and have substantially reduced applications of insecticides, including several broad spectrum active ingredients that are moderately to highly toxic to many life forms (e.g., aldicarb, carbofuran, and methyl parathion). It is interesting to note that essentially all *Bt* cotton planted since 2005 has come in "stacked" varieties that include the Roundup Ready trait. Only Dow/Phytogen produces a competing insect-resistance trait in cotton, but acreage planted to this Widestrike cotton has been negligible through 2008.

The following estimates of the impact of GE corn and cotton on insecticide use do not take into account two significant factors:

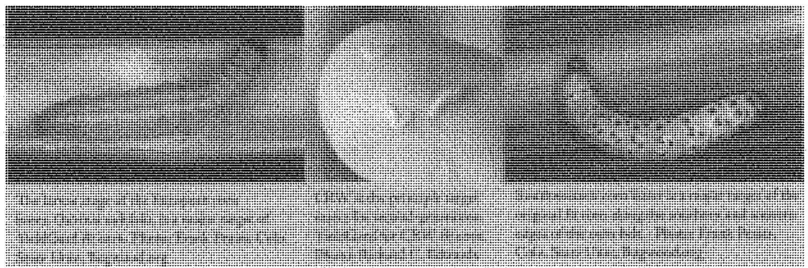
- The amount of *Bt* toxins manufactured within plant cells during a growing season; and

- The volume of insecticidal seed treatments used to help plants thrive through the early stages of growth.

As discussed in Chapter 2, there is no way to accurately project the volume of *Bt* toxins produced by a GE plant. Moreover, there is unresolved debate over whether these toxins should be counted as an "insecticide applied" for purposes of estimating the impact of GE crops on insecticide use.

In order to estimate the total pounds of *Bt* toxins manufactured by a *Bt* plant, as well as by all plants on an acre of corn or cotton, scientists need to gain better understanding of *Bt* gene expression levels in different plant tissues, how long *Bt* toxins persist in plant cells, and how the toxins break down. Such information will also prove useful in conducting more refined dietary risk assessments and to assess impacts of *Bt* toxins on soil microbial communities.

Seed treatment technology has dramatically changed in recent years. The number of pesticide active ingredients utilized in seed treatment mixtures has gone up. Most seed treatment pesticides are now encapsulated around the seed in slow release formulations that markedly extend and improve their effectiveness. The increasing use of more potent pesticides in seed treatments tends to lower the total volume of active ingredients applied as seed treatments.



A. Stacked Traits and Multiple Insecticide Formulations Muddy the Water

Projecting the impact of *Bt* traits on insecticide use has grown more complicated as a result of the trend toward stacked traits. Since 2005, a growing portion of *Bt* corn has contained both the *Bt* gene for ECB control (Monsanto's YieldGard corn) and the *Bt* gene for CRW control (Monsanto's YieldGard for CRW). Varieties expressing both *Bt* traits are referred to as "YieldGard Plus."

It is difficult to project with certainty how the three forms of *Bt* corn – YieldGard, YieldGard for CRW, and YieldGard Plus – affect insecticide use. Many insecticides applied by corn farmers are sold in more than one formulation. One formulation, a liquid spray for example, might be labeled for control of the ECB/SWCB, while a granular formulation of the same insecticide(s) is labeled for control of the CRW and other soil-borne insects.

In its annual pesticide use reports, NASS provides data by active ingredient (not formulation) on the percent of acres treated, the rate, number of applications, and pounds applied. For active ingredients in formulations effective against both the ECB/SWCB and CRW, there is no accurate way of apportioning use (i.e., share of acres treated, amount) between them, and hence a degree of uncertainty is unavoidable in identifying the insecticide acre treatments displaced by the planting of a particular kind of *Bt* corn.

Another source of uncertainty can skew estimates of the number of insecticide applications displaced by *Bt* corn. Many acres of *Bt* corn are planted on farms where conventional varieties of corn were previously planted and not routinely sprayed with insecticides for either the ECB/SWCB or CRW.

As evident in Supplemental Table 9, generally 6% to 9% of national corn acres have been sprayed for ECB/SWCB control in any given year.[1] Yet by its third year of commercial use in 1998, *Bt* corn for ECB control was planted on 19.1% of national corn acres – more than twice the average acreage typically sprayed to control the ECB/SWCB.

In 2009, over one-half of national corn acres were planted to *Bt* corn for ECB/SWCB control. Clearly, many of these acres were not previously sprayed for ECB/SWCB control; hence, the planting of *Bt* corn on these acres did not reduce insecticide use. For this reason, annual estimates are made of the percent of *Bt* corn acres that would likely have been treated with an insecticide if conventional hybrids had been planted instead, and this estimate was used in calculating the pounds of insecticides actually displaced by *Bt* corn.

In the case of *Bt* corn for CRW management, historically 27% +/- 4% of national corn acres have been treated with soil insecticides for CRW control, a share close to the 35% market penetration in 2008 of Monsanto's *Bt* corn for CRW control. Clearly, however, the availability of CRW *Bt* corn has not eliminated the use of corn soil insecticides.

1 A 2000 NAS study, "Genetically Modified Pest-Protected Plants: Science and Regulation (2000), on *Bt* crops reported that 5.2% of corn acres in the Corn belt have been historically sprayed with insecticides for ECB. The percent of corn sprayed for the SWCB is higher in states surrounding the Corn belt, which is why this report estimates that 6% to 9% of national corn acres have been sprayed in most years.

B. Insecticide Use Displaced by Two Types of *Bt* Corn

Bt corn for ECB/SWCB control has had a modest, but positive impact in reducing insecticide applications to corn, while *Bt* corn for the CRW is having a more significant impact. There is a significant degree of uncertainty in the estimates of the impacts of *Bt* corn for CRW control on insecticide use. Only 5% of national corn acres were planted to CRW hybrids in the last year NASS collected corn insecticide use data (2005). The big jump upward in *Bt* corn acres for CRW control came in 2007 and 2008.

There is little publicly accessible information on corn insecticide use in recent years as a result of the decision by NASS in 2007 to suspend the annual pesticide use surveys in major field crops like corn.

Bt Corn for ECB Control

The introduction of *Bt* corn in 1997 increased research focus and funding for work on ECB/SWCB management and heightened grower awareness of the damage caused by these insects in some seasons. As a result, many farmers became more aggressive and pro-active in managing ECB/SWCB.

For example, in 2003 corn farmers planted 25 million acres to *Bt* corn and a projected 5.4 million acres were sprayed with insecticides for ECB/SWCB control, for a total acreage under active ECB management of 30.4 million acres. This total reflects about a four-fold increase over historical levels. Some university entomologists are urging farmers to rethink their decision to automatically plant *Bt* corn for ECB/SWCB in those parts of the Corn belt where population levels are usually low.[2]

While sound advice, more and more corn farmers will be unable to act on it since the majority of corn hybrids offered for sale now include the *Bt* gene for ECB/SWCB control.

[2] For an intriguing assessment of trends in corn insect pest management, including the over-reliance on *Bt* corn, see Steffey, K., and Gray, M., (2009). "IPM and the Integrated Control Concept: Progress after 50 Years in the Commercial Corn and Soybean Landscape?," *The Bulletin*, University of Illinois Extension, No. 1, Article 5, March 19.

Supplemental Tables 9 and 11 set forth the basis for estimating the impact of *Bt* corn for ECB/SWCB control on corn insecticide use. Supplemental Table 9 projects the average rate of insecticides applied on conventional corn to control the ECB/SWCB, relying on NASS data on corn insecticide use. Since no NASS data have been collected since 2005, insecticide use rates for 2006-2008 were assumed to remain unchanged. No important new active ingredients have come on the market and attained significant corn use in this period, so it is very likely that average use rates have changed little since 2005.

University experts and insect-control guides were consulted to determine which corn insecticides target the ECB largely or exclusively, and which insecticides are partially applied for ECB control. The same was done for the CRW insecticides.

These percentages are incorporated in Supplemental Tables 9 (ECB/SWCB rates) and 10 (CRW rates). Average insecticide use rates for products targeting the ECB/SWCB were then calculated based on the weighted shares of total national corn acres treated for ECB/SWCB control.

The average rate of application of corn insecticides targeting the ECB fell gradually from 0.21 pounds in 1996 to 0.13 pounds in 2008, consistent with the long-term downward trend in the application rates of registered pesticides. Farmers relied less heavily on organophosphate insecticides applied at rates of 0.5 to 1.2 pound per acre, and more heavily on synthetic pyrethroid insecticides applied at rates between 0.01 and 0.1 pounds per acre.

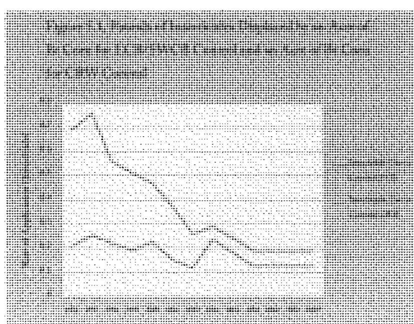


Figure 5.1 shows the generally downward trend in the rate of insecticide applications displaced by the planting of *Bt* corn for ECB/SWCB control, as well as *Bt* corn for CRW management.

Supplemental Table 11 calculates the percent of corn acres planted to ECB *Bt* corn, the number of acres planted each year, and the likely number of acres planted that would previously have been treated with an insecticide. As a result of this adjustment, *Bt*-ECB acres that would have been sprayed absent *Bt* technology changes from 90% in 1997 to 45% in 2007-2008 (see Chapter 2D for the rationale behind these adjusments).

The line in Supplemental Table 11 labeled "Adjusted Volume of Insecticide Displaced by a *Bt*-ECB Acre" is the estimated rate of insecticide applications for ECB/SWCB control from Supplemental Table 9 multiplied by the percent of *Bt* corn for ECB control that would have previously been treated with an ECB insecticide. This step addresses the previously described source of upward bias in estimates of insecticide applications displaced by *Bt* corn (i.e., the fact that not all acres planted to a *Bt* hybrid would have been sprayed with an insecticide if conventional corn had been planted).

Bt Corn for CRW Control

The impact of *Bt* corn for CRW control is projected in the same way as the impact of ECB *Bt* corn, as shown in Supplemental Tables 10 and 11. *Bt* corn for CRW control was introduced as a single-trait variety in 2003 and was planted on less than one percent of national corn acres in that year. By 2008, over one-third of national corn acres were planted to a variety expressing the CRW *Bt* gene.

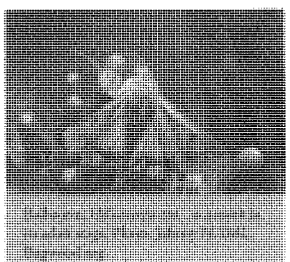
The average pounds of insecticides applied per acre of corn to treat the CRW and related soil-borne insects are calculated in Supplemental Table 10. The volume of insecticides applied for CRW control fell from 0.29 pounds per acre in 2003 to 0.19 in 2005-2008, as shown in Figure 5.1. This reduction was driven by the shift away from relatively high dose insecticides to lower-dose active ingredients applied at rates between 0.01 and 0.1 pound per acre.

As with ECB *Bt* corn, the percent of corn acres under active management for the CRW – seed treatments, *Bt* genes, and conventional insecticides -- has far outpaced the historic percent of corn acres sprayed with an insecticide for CRW control. Accordingly, the percent of acres planted to CRW *Bt* corn that would have previously been treated with an insecticide is adjusted from an estimated 95% in the first year of adoption in 2003, to 60% in 2008, for reasons discussed further in Chapter 2.

Accordingly, the model projects in 2008 that 18 million acres of corn were not sprayed for CRW as a result of the planting of *Bt* corn for CRW control (0.6 x 30.1 million acres of *Bt* CRW corn).[3] In addition to these *Bt* acres, an estimated 8 million more acres were sprayed with a CRW insecticide, for a total of 38 million acres that were directly treated during the growing season. In addition, essentially all national corn acres were treated with a seed treatment targeting the CRW.

C. *Bt* Cotton Continues to Perform Well

Essentially 100% of the acres planted to *Bt* cotton were previously sprayed for control of the budworm/bollworm complex of insects – the prime target of *Bt* cotton. Moreover, *Bt* cotton is highly effective, so each acre planted is assumed to displace the average pounds of insecticides previously sprayed on an acre of conventional cotton for budworm/bollworm control.



Accordingly, estimating the difference in insecticide use on acres planted to *Bt* and conventional cotton varieties is simpler than in the case of *Bt* corn. Plus, NASS surveyed cotton pesticide use in 2007, reducing the need for assumptions in extrapolating current use rates.

Estimates of the average pounds of insecticides displaced by each acre of *Bt* cotton are shown in Supplemental Table 12.

3 Monsanto's overview of biotechnology trait acreage dated June 24, 2009 reports that 30.1 million acres were planted to the CRW trait.

The percent of cotton acres planted to *Bt* varieties rose from 12% in 1996 to 52.5% in 2004 and reached 73% in 2008.

NASS pesticide use data includes the percent of crop acres treated with 11 insecticides known to target the budworm/bollworm complex, including organophosphates, synthetic pyrethroids, carbamates, liquid *Bt* sprays, and two reduced-risk insecticides, emamectin benzoate and indoxacarb. The extremely toxic carbamate insecticide aldicarb was the market leader throughout this period, accounting for one-half to two-thirds of the acres treated over the 13-year period.

Many of these insecticides were applied multiple times, and hence it is necessary to calculate the number of cotton acre-treatments with each insecticide, in order to calculate the weighted average rate of application per crop year (taking into account multiple applications). In 1996, the year *Bt* cotton was introduced, aldicarb accounted for 28% of the acre-treatments, followed by methyl parathion at 25%. The share of total acre-treatments accounted for by each of the 11 insecticides was used in calculating the weighted average rates in the last line in Supplemental Table 12.

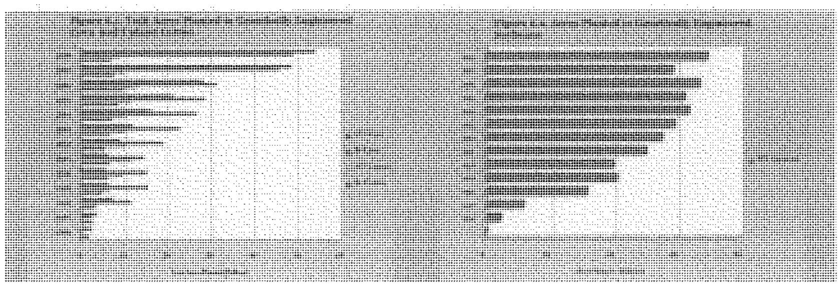
The average budworm/bollworm insecticide application rate in 1996 was 0.56 pound per acre. The rate has dropped gradually to 0.47 pounds in 2008. The limited decline in cotton insecticide rates reflects the growing percentage of acre treatments accounted for by aldicarb, an insecticide applied at the rate around 0.6 pounds per acre. By 2008, the percenr of cotton acres treated with insecticides for the budworm/bollworm complex had fallen from 48% to 25%, but aldicarb's share of the total number of acre-treatments had risen from 28% to 67%.

6. Aggregate Impacts of GE Crops on Pesticide Use: The First Thirteen Years

Corn, cotton, and soybeans account for nearly all GE crops grown in the U.S. since 1996. About 941 million acres have been planted to corn, soybeans and cotton with herbicide tolerance, while 357 million acres of corn and cotton have carried the *Bt* trait, for a total of 1.3 billion GE trait acres over the 13 years covered by this study (see Figures 6.1 and 6.2). As explained in Chapter 3, the actual area planted to GE crops over this period is substantially less than 1.3 billion acres due to the growing prevalence of stacked crops that contain both HT and *Bt* traits.

The same pattern is evident with HT cotton. Each acre of HT cotton in 1996 reduced herbicide use by three-quarters of a pound, but by 2001, rising glyphosate use on HT acres had overtaken the average pounds applied on conventional acres.

Today, each acre of HT cotton increases the average pounds of herbicides applied by about two-thirds relative to conventional cotton. RR soybeans reduced average herbicide use by 0.3 pounds per acre planted in 1996. Just two years later, USDA data show that average herbicide use on HT soybean acres had already risen above the average rate on acres planted to conventional soybeans. By 2008, the difference had increased to 1.16 pounds per acre.



A. Major Findings and Conclusions

Differences in the pounds of pesticides applied on acres planted to GE varieties, compared to acres planted to conventional seeds, are reported in Supplemental Table 7.

HT corn reduced herbicide use in its first year of introduction by almost 0.8 pounds per acre. Over time, increases in the average rate of application of glyphosate drove herbicide use upward on HT acres.

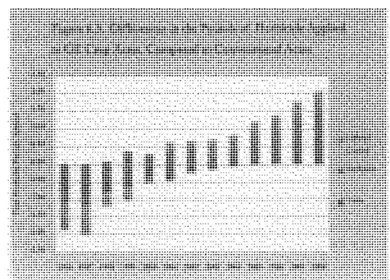
By 2005, herbicide use on conventional and HT corn acres was essentially identical and by 2006, the average pounds applied on an HT corn acre had risen to 0.08 pounds above the average pounds of herbicides applied to an acre of corn planted to a conventional variety.

This dramatic change in herbicide application rates is unmistakable in USDA surveys of pesticide use on soybean farms. There is also general agreement on why the performance of RR soybeans has changed so dramatically over the years – intense selection pressure from excessive reliance on glyphosate has triggered weed shifts to species more tolerant of glyphosate, as well as evolution of glyphosate-resistant biotypes.

As is the case with corn and cotton, steady reductions over the 13 year period in average soybean herbicide application rates per acre also contributed to the growing margin of difference in overall herbicides applications on RR versus conventional crop acres. These reductions were brought about by the registration and growing market penetration of several low-dose herbicide products.

Figure 6.3 portrays these trends in the differences in pesticide use on an acre planted to a GE crop, compared to an acre planted to a conventional variety.

Estimates of the impacts of GE crops on pesticide use have been calculated by crop, trait, and year. The annual change in the volume of pesticide use triggered by the planting of an acre of GE crop (Supplemental Table 7) is multiplied by the acres planted to each GE trait, producing the values in Supplemental Table 8. A graphic depiction of the overall impact of GE crops on pesticide use from 1996 through 2008 appears in Figure 6.4.



Key Conclusions

Over the first 13 years of commercial planting of major GE crops in the United States, this analysis shows that:

- GE crops increased overall pesticide use by 318.4 million pounds, or by 7.5% of combined use on the three crops;

- Herbicide tolerant crops increased herbicide use by 382.6 million pounds, while *Bt* crops reduced insecticide use by 64.2 million pounds;

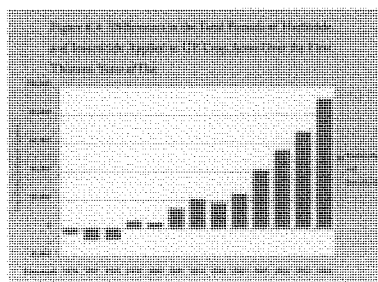
- Herbicide tolerant soybeans accounted for 92% of the increased herbicide use across the three HT crops;

- GE crops reduced pesticide use in the first three years of commercial introduction by 1.1%, 2.3%, and 2.3% per year, but rising rates per crop year of glyphosate on RR varieties increased aggregate pesticide use across all GE traits and acres beginning in 1999;

- Rates of corn and soybean herbicide and corn insecticide applications on cropland planted to conventional varieties trended downward during the study period by 24% to over 90% as a result of the shift toward lower-dose pesticides;

- The 26% increase in the pounds of pesticides applied on GE crops in 2008, compared to acres planted to conventional varieties, was almost five-fold greater than the 5.8% increase just five years earlier, in 2003; and

- The upward trend in pesticide use on GE crops has been driven almost solely by the rapid emergence and spread of weeds tolerant of or resistant to glyphosate.



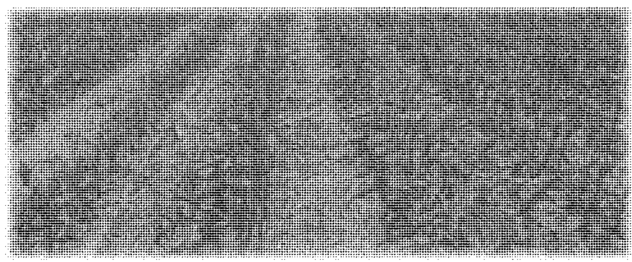
Moreover, further increases in overall pesticide use on GE crops is inevitable in 2010 and for the foreseeable future in the U.S. because of the further emergence and steady spread of weeds resistant to glyphosate.

B. Estimates in Other Studies

U.S. Department of Agriculture

The USDA has done very little research on the impacts of GE crops on pesticide use, and has been essentially silent on the topic for about a decade. A report by the ERS was issued in May 2002 entitled *Adoption of Bioengineered Crops*.[1] A short section addresses the impacts of GE crops on pesticide use

[1] Fernandez-Cornejo, J., and McBride, W., (2002). Agricultural Economic Report No. 810.



between 1997 and 1998 for HT soybeans and cotton and *Bt* cotton, and between 1996-1997 for HT corn. Across the three major crops, the ERS analysts estimated a reduction of 2.5 million pounds of pesticides applied, very close to the 2.2 million pounds reduction estimated in this report for the corresponding years.

This 2002 ERS report concluded that herbicide use on HT soybeans went up in 1998 because 13.4 million pounds of glyphosate were substituted for 11.1 million pounds of other herbicides. The ERS projection of a 2.3 million pound increase in herbicide pounds applied on HT acres is also very close to the 2.2 million pound increase based on the methodology used in this report.

USDA's report *Agricultural Resources and Environmental Indicators, 2006 Edition*, addresses the adoption and impacts of GE crops.[2] The section on pesticide use restates the findings of the May 2002 report

It also states that overall pesticide use in corn, soybeans and cotton, on GE and conventional acres, has declined from 1995 to 2002 (based on NASS annual pesticide surveys). For some unexplained reason, however, the authors of this 2006 report neglect to include available NASS pesticide data for later years, including herbicide use data on corn and cotton for 2003, which show substantial increases in per acre use rates on corn (10% rise from 2002 to 2003) and cotton (20% rise from 2001 to 2003). In addition, the authors imply, but do not justify, a linkage between the reduction in overall pesticide use through 2002 and the adoption of GE crops. Nor does the ERS report acknowledge the sizable reductions in average herbicide and insecticide application rates on conventional crops during this period.

There is no discussion of the impact of GE crops on pesticide use in the current version of the "Agricultural Biotechnology" Briefing Room on the ERS website.[3] No other official reports have been issued by USDA addressing the overall impact of GE crops on pesticide use.

National Center for Food and Agriculture (NCFAP) Policy Studies

Several simulation studies by the National Center for Food and Agriculture Policy (NCFAP), an organization funded in part by the biotechnology industry, have addressed the impact of GE crops on pesticide use. The most recent report was released in November 2006 and projects impacts in crop year 2005.[4]

NCFAP's general method is to simulate pesticide use on GE and non-GE crops by simply extrapolating from particular pest management systems recommended by university extension agents for adoption on all GE and

2 Wiebe, K. and Gollehon, N., eds. (2006). USDA Economic Research Service Number 16, July 2006, see Chapter 3.3 at http://www.ers.usda.gov/Publications/AREI/EIB16/. For an essentially identical treatment based on 1990s data, see: Fernandez-Cornejo, J. and Caswell, M. (2006). "The First Decade of Genetically Engineered Crops in the United States," USDA ERS Economic Information Bulletin No. 11, April, pp. 11-13.

3 http://www.ers.usda.gov/Briefing/Biotechnology/; accessed September 18, 2009.

4 Sankula, S.,"Quantification of the Impacts on US Agriculture of Biotechnology-Derived Crops Planted in 2005," National Center for Food and Agricultural Policy, Washington, D.C.

non-GE crop acres. Such simplistic models are highly vulnerable to error, since actual pest management systems often deviate considerably from those recommended by university specialists. The results from such models need to be checked against real-world pesticide use data whenever possible.

Herbicide-Tolerant Corn

NCFAP estimates that genetically engineered HT corn was planted on 35% of corn acres in 2005, a considerably higher share compared to NASS's corresponding figure of 26%, a discrepancy that is not noted or explained by NCFAP. Based on this 35% figure, NCFAP estimates that GE HT corn reduced herbicide use by 21.8 million pounds in 2005, or about 0.8 pounds per acre.

This finding rests largely on two faulty assumptions that exaggerate the amount of herbicide applied to conventional/non-HT corn acres, which in turn inflates the "reduction" from a switch to HT corn. These faulty assumptions relate to the extent and rate of use of two high-dose herbicides, atrazine and s-metolachlor/metolachlor, that are used on both HT and conventional/non-HT[5] corn.

With regard to extent of use, NCFAP assumes that all non-HT corn farmers apply two premixed products: first, a mixture of the high-dose herbicides s-metolachlor and atrazine (preemergence), followed post-emergence by a product consisting of mesotrione, nicosulfuron and rimsulfuron.

NASS data demonstrate clearly that the atrazine-metolachlor premix could not have been used by a majority of, much less all, farmers planting non-HT corn. According to NCFAP, non-HT corn comprised 65% of national corn acres, while NASS reports that just 25% of all corn was treated with either s-metolachlor or metolachlor, so that at most 25% of corn acres were treated with this premix (atrazine was applied to 66% of corn acres). At most, 38% of non-HT corn acres could have been treated with this high-rate premix (25% maximum treated, divided by 65% planted).

NCFAP also overestimates the rate of herbicide applied to non-HT acres. NCFAP assumes that non-HT corn farmers apply the s-metolachlor/atrazine premix at 3.16 pounds of active ingredients per acre, and the low-dose post-emergence mix at 0.07 pounds per acre, for a total of 3.23 pounds per acre. However, NASS reports that the average amounts of atrazine and s-metolachlor applied to all corn in the 2005 season were 1.13 and 1.35 pounds per acre, respectively. Accordingly, the combined average rate of atrazine and s-metolachlor applied via the premix was at most 2.48 pounds of active ingredient per acre, much less than the 3.16 pounds assumed by NCFAP.

NCFAP projects that an average of 2.5 pounds of herbicides were applied on RR corn acres in 2005, resulting in a 0.73 pound per acre reduction (3.23 pounds on conventional acres, minus 2.5 pounds on RR acres). NCFAP would have projected a 0.02 pound increase on HT acres had it used the more realistic NASS application rates for atrazine and s-metolachlor on conventional corn. The methodology in this report projected a 0.01 pound reduction in per acre herbicide use on HT acres in 2005.

Herbicide-Tolerant Soybeans

In the case of soybeans, NCFAP both underestimates herbicide use on HT acres and overstates the amount applied to conventional acres. These faulty assumptions result in a simulated and illusory "reduction" of 20.5 million pounds nationally from the planting of HT soybeans in 2005. HT soybeans – all Roundup Ready – were planted on nearly 90% of national soybean acres in 2005.

NCFAP wrongly assumed that one application of glyphosate sufficed for over 80% of Roundup Ready soybean acres, resulting in a simulated 1.18 glyphosate applications to the average RR soybean acre for the year. In contrast, NASS reported an average of 1.5 applications of glyphosate (28% higher), a figure that reflects the need for two or more glyphosate applications to control resistant weeds in many states (see Chapter 4). Similarly, NCFAP's estimate of total herbicide applied to RR soybeans – 1.03 pounds per acres per year – does not even match the annual NASS figure for glyphosate alone, which is 1.1 pounds per acre, much less account for non-glyphosate herbicides applied to RR soybeans.

5 In the following discussion, the term "non-HT" encompasses both conventional corn and GE corn that does not contain an HT trait (i.e., single-trait *Bt* corn).

NCFAP assumes, for reasons not explained, that herbicides in addition to glyphosate were applied to RR soybeans in just one state (Iowa). In Iowa, NCFAP assumes that soybean farmers apply 0.19 pounds per acre of Canopy (a premix of chlorimuron and metribuzin), in addition to one application of glyphosate. In contrast, this report more realistically estimates that non-glyphosate herbicides were applied to RR soybean acres at an average rate of 0.12 pounds per acre in 2005.

NCFAP also vastly overstates the amount of herbicides applied to conventional soybean acres in 2005, assuming average total applications of 1.35 pounds per acre (all presumed to be non-glyphosate herbicides). This presumed rate for herbicides applied to conventional soybean acres is more than twice the rate of 0.59 pound per acre on conventional soybeans estimated in this study, based on NASS data. NCFAP's estimate of average herbicide use on convenrional soybeans is clearly out of step with the trend toward lower-dose herbicides, some of which are applied at rates well below 0.1 pound per acre.

If NCFAP had used NASS data to calibrate its estimates of herbicide use on RR and conventional soybean, it would have arrived at a result much closer to the one in this report: an estimated increase in herbicide use of 41.5 million pounds in 2005 due to the planting of RR soybeans (see Supplemental Table 8).

PG Economics Ltd

A UK based consulting firm, PG Economics Ltd., has carried out several studies of GE crops funded by the pesticide and biotechnology industries. Their latest was released in May, 2009.[6] The PG Economics report uses methods and sources similar to NCFAP, and claims its estimates are based on "the average performance and impact recorded in different crops."

The PG Economics report estimates a 4.6% reduction worldwide in herbicide use attributable to GE crops from 1996 through 2007 (the first 12 years of commercial use). This report estimates that GE HT corn, soybeans, and cotton have increased herbicide use in the U.S. by 382 million pounds over 13 years, or by about 10% (NASS reports that 3.82 billion pounds of herbicides applied to these three crops from 1996-2008). It is worth noting that the increase in 2008 – the extra year covered by this analysis – was 100 million pounds, or about 26% of the total increase over the 13 years.

The methodology in the PG Economics report is worth a closer look. HT soybeans are by far the most important GE crop in the U.S. in terms of impacts on pesticide use, and so the focus herein is on the PG Economics analysis of herbicide use on conventional and HT soybeans, as set forth in Chapter 4 of their above-cited report.

The authors begin by noting that there are two primary sources of data on pesticide use in the U.S. – NASS surveys and private farm-level surveys (survey data from DMR Kynetec was used in the PG Economics report).

Their Table 33 reports herbicide use on HT and conventional soybeans for 1998 through 2007 in the U.S., based on Kynetec survey data. In every year, herbicide use was higher on HT soybeans than conventional soybeans. The margin was typically less than 0.2 pounds until 2002, when the margin increased to around 0.3 from 2003-2007, as shown in Table 6.1.

Estimates of herbicide use on HT soybean acres as reported in the PG Economics report and this analysis differ modestly, and are accounted for largely by the rate per crop year of glyphosate herbicides. Likewise, the PG Economics and this report's estimates of total herbicide use on conventional soybean acres, and the differences between HT and conventional acres, are relatively close for 1998 through 2004. The Kynetec dataset then projects increases in the total rate of herbicide application on conventional acres from 2004 through 2007, despite the continued trend toward greater reliance on relatively low-dose herbicides, as evident in the projections based on NASS data.

This deviation in estimates of herbicide use on conventional soybeans accounts for this report's progressively larger margin of difference in herbicide use rates on HT in contrast to conventional soybean acres.

Despite some differences, it is significant that the industry-sponsored Kynetec survey, as reported by PG Economics, supports the same basic conclusion as this report – HT soybeans have increased herbicide use by a substantial and growing amount.

6 Brookes, G., and Barefoot, P., "GM crops: global socio-economic and environmental impacts 1996-2007," PG Economics Ltd, UK, Dorchester, UK.

"The comparison data between the GM HT crop

Table 6.1. Impacts of HT Soybeans on Herbicide Use as Projected by Kynetec Data and This Analysis Based on NASS Data [NA="Not Available"]

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Pounds Applied HT Acres											
Kynetec	1.33	1.29	1.32	1.34	1.3	1.39	1.41	1.4	1.33	1.48	NA
NASS-Based	1.2	1.2	1.18	1.07	1.31	1.32	1.22	1.25	1.5	1.58	1.65
Pounds Applied Conventional Acres											
Kynetec	1.28	1.15	1.11	1.17	1.09	1.07	1.08	1.1	1.02	1.16	NA
NASS-Based	1.13	0.84	0.9	0.73	0.88	0.97	0.8	0.59	0.7	0.52	0.49
Difference HT to Conventional Acres											
Kynetec	0.05	0.14	0.21	0.17	0.21	0.32	0.33	0.3	0.31	0.32	NA
NASS-Based	0.07	0.36	0.28	0.34	0.43	0.35	0.42	0.66	0.8	1.06	1.16

and the conventional alternative presented above is, however, not a reasonable representation of average herbicide usage on the average GM HT crop compared with the average conventional alternative for recent years." (page 66)

The PG Economics analysts disavow their own data-driven estimates, asserting that herbicide use is lower on conventional soybean acres in the Kynetec dataset because the majority of farmers planting conventional soybeans must be among those facing the lightest weed pressure. This creative argument, however, is incompatible with the pattern of adoption of HT soybeans across the states. Since 2006, the rate of adoption of HT soybeans varies modestly between states from 81% to 97%, with no clear pattern between states with relatively low weed pressure (Minnesota, South Dakota) and states with much higher levels of weed pressure (Mississippi, Arkansas).[7]

After rejecting the Kynetec survey findings that were based on real data, the PG Economics team then turns to another source for supposedly more reliable estimates – the National Center for Food and Agricultural Policy (see previous section for a critique of NCFAP's estimates). The PG Economics team revises its soybean herbicide use projections drawing on NCFAP's faulty simulations, and reaches the basic finding of a 6.8% reduction in herbicide use as a result of HT soybeans.

Similarly creative – and highly questionable – methodological strategies are employed by the PG Economics team in projecting the impacts of other GE crops on pesticide use. Like the NCFAP, the PG Economics team never explains the discrepancies between their estimates and those based on NASS data.

Genetically engineered corn, soybeans, and cotton now

[7] Supplemental Table 3 presents HT soybean adoption rate data by state, and shows that some relatively low weed pressure states have high adoption, while others have lower adoption. Several relatively low pressure states have higher adoption rates than states with high levels of weed pressure.

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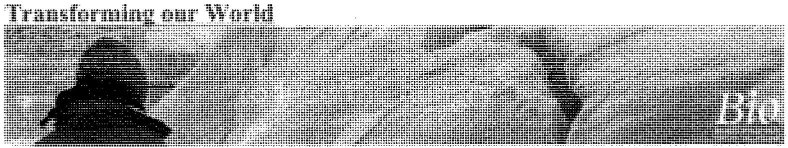

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Agricultural Biotechnology – Providing Economic and Environmental Benefits

Posted by susanathio on May 21st, 2009 — BIO Events & Activities, Food & Agriculture [1 Comment]

By Michael J. Phillips

Further evidence was provided at BIO 2009 on the many benefits of agricultural biotechnology. Graham Brookes, Director of PG Economics (UK) released key findings from its Global Impact Study that showed that farmers around the world are growing more biotech crops with significant global economic and environmental benefits. Key highlights of the report include:

- Biotech crops contribute significantly to reducing the release of greenhouse gas emissions from agricultural practices – mainly from less fuel use and additional soil carbon storage from reduced tillage. In 2007, the reduction of carbon dioxide from the atmosphere by biotech crops was equivalent to removing nearly 6.3 million cars from the road for one year;

- Biotech crops reduced pesticide use (1996-2007) by 359 million kg (-8.8 percent), and as a result, decreased the environmental impact associated with herbicide and insecticide use on the area planted to biotech crops by 17.2 percent;
- Herbicide tolerant biotech crops have facilitated the adoption of no/reduced tillage production regions – especially South America;
- There have been substantial net economic benefits to farmers amounting to $10.1 billion in 2007, and $44.1 billion since 1996. Of the $44.1 billion, 46.5 percent ($20.5 billion) was due to increased yields and the rest to reductions in the cost of production.

The report countered a recent Union of Concerned Scientists (UCS) report that attempted to make the case that biotech crops have not significantly increased yields since their introduction 1996. However, the UCS report suffers from a very flawed, superficial and inconsistent analysis.

The UCS report is very selective in the data it chose to use and does not account for variation in yield, country and region. The UCS report does – in fact – state that Bt corn has increased yields in the United States, but states just the opposite in its executive summary. In addition, the report did not take into consideration the significant decrease in costs of production from biotech crops that are just as important to farmers as yield. And, the report did not include canola and cotton that have had significant yield increases over the past decade.

The findings of the PG Economics report were featured at the Biotechnology Industry Organization (BIO) 2009 conference and subsequently used by most biotechnology and pesticide industry trade associations in public relations efforts designed to promote awareness of the benefits of GE crop technology. Note that in this posting by Michael Phillips, BIO Vice President for the Food & Agriculture program, the PG Economics report is highlighted as a "counter" to the 2004 UCS report on the impacts of GE crops on pesticide use over the first nine years of commercial use.

7. The Road Ahead for Today's GE Crops

dominate the market. Across these three crops, the supply of conventional, non-GE seed is so thin now that GE seeds will continue to account for the majority of crop acres planted for at least several years to come.

The quantum leap in seed industry profits associated with the marketing of GE seeds, coupled with control of the seed supply by companies holding the patents on GE technology, virtually guarantee this outcome. But there are clouds on the horizon for both the biotech industry and corn, soybean, and cotton farmers. Resistant weeds will continue to emerge and spread, and the current pressure to relax resistance management plans applicable to *Bt* corn and cotton could undermine long-term efficacy.

Over the next decade, GE seeds will increasingly contain multiple traits, cost considerably more per acre, and pose unique and not well understood resistance management, food safety and environmental risks. These factors will assume ever greater importance in assessments of the costs, benefits, and risks of GE crop technologies.

A. The Tipping Point for RR Crops

In the 2009 crop year, the percentage of national soybean acres planted to Roundup Ready varieties decreased for the first time since their introduction in 1996. Though the decline in adoption was slight (92% to 91%), there are reasons to believe 2009 may mark the tipping point for RR soybean market penetration. These include the slipping efficacy of the RR system as glyphosate-resistant weeds spread, steeply rising production costs (RR seed, herbicides), early evidence that the 7% to 11% yield increase promised by Monsanto on farms planting Roundup Read 2 soybeans is not occurring in the field[1]; and the increasingly attractive economics of growing conventional soybeans.

The spread of glyphosate-resistant weeds is largely responsible for the sharply increased use of glyphosate on soybeans documented in this report. While incrementally higher glyphosate application rates, and more applications, on RR crop acres will further increase overall glyphosate use, resistant weeds will force a growing number of farmers to resort to additional herbicides as well. As an Iowa State University weed scientist argues in a prescient article entitled "Turn Out the Lights -- The Party's Over," the days have passed when a single, properly timed application of glyphosate controlled all weeds, all season long.[2]

In the future, most RR acres will be treated with two herbicide active ingredients including glyphosate, and many will be sprayed with three or more, often in multiple-product premixes.

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1 A study carried out in five states involving 20 farm managers who planted RR2 soybeans in 2009, concluded that the new varieties "didn't meet their [yield] expectations." Source: Jack Kaskey, "Monsanto Facing 'Distrust' as It Seeks to Stop DuPont," Bloomburg.com, November 11, 2009. http://www.bloomberg.com/apps/news?pdi=newsarchive&sid-acv4aBI1Q4Ng

2 Hager, A. (2009). "Turn Out the Lights – The Party's Over," *The Bulletin*, University of Illinois Extension, No. 3 Article 4, April 10.

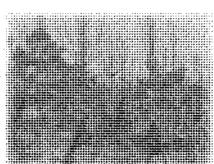
As a result, growers planting RR crops will find themselves facing weed control regimes that are more complex, time-consuming, and expensive than those utilized by conventional corn, soybean, and cotton farmers.

Some farmers have already decided to explore life after RR soybeans. "Interest in Non-Genetically Modified Soybeans Growing" is the title of an April, 2009 story posted by the Ohio State University extension service. Growing interest stems from "cheaper seed and lucrative premiums [for non-GE soybeans]."[3] In anticipation of this growth in demand, the Ohio State extension service reports that seed companies are doubling or tripling their conventional soybean seed supply for 2010.

Similar reports are coming in from Missouri and Arkansas,[4] where demand for cheaper conventional soybeans that yield as well as or better than RR soybeans is outstripping supply. Agronomists in these states point to three factors driving this renewed interest in conventional soybean seed:

- The high and rising price of RR seed;
- Resistant and tougher-to-control weeds; and
- Regaining the option and freedom to save and replant seeds, a traditional practice prohibited with Monsanto's patented RR soybeans.

The cost of soybean seed has risen from around $10 per bushel in the early 1980s to around $50 for RR seed in 2008. Monsanto recently announced that the newly introduced RR 2 soybean seed will cost $74 an acre in 2010, a remarkable 42% increase from 2009.[5]



The rapid spread of horseweed, Palmer amaranth, and other weeds resistant to glyphosate will force soybean and cotton farmers to apply higher rates of glyphosate and make additional applications of it, as well as other herbicides. Already in 2006, it was estimated that controlling GR Palmer amaranth would increase cotton production costs by $40 or more per acre.

For many soybean farmers in the Southeast, increased costs in 2010 are likely to include:

- A $24 per acre increase in cost for RR 2 soybean seed;
- About $15 more per acre for additional Roundup (depending on whether and to what degree glyphosate prices are reduced); and
- Up to $40 per acre for additional herbicides targeting glyphosate-resistant weeds.

The potential $79 increase in costs associated with the RR 2 system in 2010 in the Southeast is roughly equal to 60% of forecasted soybean cash operating costs, and would represent a remarkable 28% of soybean income per acre over operating costs, based on USDA's forecast for 2010.

Resistant weeds are not confined to the particularly damaging Palmer amaranth in the Southeast, but have rapidly emerged throughout the Midwest as well. Glyphosate-resistant biotypes of four different weed species have been documented in Kansas, three each in Missouri and Ohio, and two each in Minnesota, Indiana and Illinois. Up to one million acres of glyphosate-resistant horseweed were recently documented in Illinois, with up to 100,000 acres in Missouri and Kansas. This emergence of resistant weeds in the Midwest was predicted years ago,[6] and is the result of widespread planting of RR soybeans, often in rotation with RR corn, especially in recent years.

3 Pollack, C. (2009). "Interest in Non-Genetically Modified Soybeans Growing," Ohio State University Extension, April 3, 2009, http://extension.osu.edu/~news/story.php?id=5099

4 Jones, T. (2008). "Conventional soybeans offer high yields at lower cost," University of Missouri, Sept. 8, 2008. http://agebb.missouri.edu/news/ext/showall.asp?story_num=4547&iln=49; Medders, H. (2009). Soybean demand may rise in conventional state markets," University of Arkansas, Division of Agriculture, March 20, 2009. http://www.stuttgartdailyleader.com/homepage/x599206227/Soybean-demand-may-rise-in-conventional-state-markets

5 Kaskey, J. (2009). "Monsanto to Charge as Much as 42% More for New Seeds," Bloomberg, August 13, 2009. http://www.bloomberg.com/apps/news?pid=20601103&sid=aLW8VZBkP3PA#

6 Owen, M.D.K. (2005). "Update 2005 on Herbicide Resistant Weeds and Weed Population Shifts," 2005 Integrated Crop Management Conference, Iowa State University.

"Roundup is the greatest thing in agriculture in my lifetime."

"In hindsight, we screwed up. We can't rely on the same thing over and over."

Quotes from a North Carolina farmer and a retired scientist[7]

B. Industry's Response to Resistant Weeds

While biotechnology companies generally downplay the severity and adverse impacts of glyphosate-resistant weeds, they are nonetheless working aggressively to come up with responses to the problem. Three of these responses are discussed below: subsidies for use of herbicides with different modes of action, crops with enhanced resistance to glyphosate, and herbicide-resistant stacks that include resistance to toxic but inexpensive herbicides like 2,4-D.

Subsidies for Use of Non-glyphosate Herbicides

Since 1996 Monsanto has encouraged farmers to rely exclusively on glyphosate for control of weeds in Roundup Ready crops,[8] and discounted the possibility of significant problems triggered by glyphosate-resistant weeds.[9] Now that resistant weeds are threatening the viability of the RR crop system, however, Monsanto and other companies are responding with unprecedented initiatives that subsidize the purchase of competitors' products in a belated effort to deal with already-resistant weeds and/or slow the emergence of newly resistant weeds.

Monsanto's "Start Clean, Stay Clean Assurance Plan" is part of the Roundup Rewards program,[10] which offers farmers rebates and incentives for those farmers who agree to exclusively purchase specific, bundled Monsanto seed

[illegible]

and herbicide products.[11] Under this program a farmer can receive a rebate up to $13 per acre for the purchase of a competitor's herbicide that works through a mode of action different from Roundup's.

The "Roundup Ready Cotton Performance Plus" program also offers rebates from Monsanto to growers to cover the cost of competitors' herbicides. This program pays up to $12 per acre and is designed to encourage the rotation of herbicide modes of action, a core resistance management practice.[12]

Syngenta, too, has recently announced a plan, the "2009 AgriEdge Corn and Soybean Program"[13] that offers rebates for the purchase of herbicides that work through a mode of action other than glyphosate's.

Although the rotation of herbicide modes of action is an important strategy for sustaining herbicide efficacy, the rotations must be done carefully. As the pesticide industry

7 Quotes from the article "Carolina farmers battle herbicide-resistant weeds," by Jeff Hampton, *The Virginia-Pilot*, July 19, 2009.

8 Shaner, D.L. (2000). "The impact of glyphosate-tolerant crops on the use of other herbicides and on resistance management," *Pest Management Science* 56: 320-26.

9 Bradshaw LD, Padgette SR, Kimball SL and Wells BH (1997). "Perspectives on glyphosate resistance," *Weed Technol* 11:189–198.

10 The 32 page brochure that explains the Roundup Rewards program and presents details on the rebates for purchase of herbicides sold by other companies is accessible at http://www.monsanto.com/monsanto/ag_products/pdf/rr_rewards_brochure.pdf.

11 Offering rebates contingent on exclusive purchase of a single company's products, or requiring farmers to purchase one input in order to have access to another is a practice called "bundling" which is, in general, frowned upon by the Federal Trade Commission and Justice Department. Some farm leaders have called for a government investigation of the anti-competitive impacts of Monsanto's current marketing programs and policies.

12 "RR cotton growers can receive rebates for multiple herbicides," *Carolina-Virginia Farmer*, February 2009.

13 For more details, see http://www.garstseed.com/GarstClient?GarstNews/news.aspx?NewsItem=10103.

moves to more multiple-herbicide premix products, farmers will have a more difficult time following recommended herbicide-resistant management plans. In addition, several GR weed biotypes are also already resistant to herbicides in one, two, or more herbicide families of chemistry, as documented in Chapter 4.

Enhanced Glyphosate Resistance

A second strategy to respond to the rapid spread of glyphosate-resistant weeds is engineering crops with enhanced resistance to glyphosate. Such crops will tolerate the use of higher rates of application, in the hope that more glyphosate will control increasingly resistant weeds. While of limited effectiveness in the short term, this strategy will accelerate the emergence of weeds with higher levels of glyphosate-resistance, and is, for farmers, like pouring gasoline on a fire in the hope of putting it out.

Monsanto's Roundup Ready Flex cotton, the successor to its original RR cotton, was introduced in 2006 and was the first crop variety to hit the market with enhanced glyphosate resistance.[14] The label for Roundup Ready Flex cotton recommends almost 1.5 times the glyphosate application rate, compared to original RR cotton (32 ounces/acre for RR Flex vs. 22 ounces/acre for original RR cotton).[15] In addition, RR Flex cotton permits glyphosate application on sexually mature cotton plants (unlike original RR cotton).

Bayer CropScience recently obtained commercial approval for its glyphosate-resistant Glytol cotton, which is associated with an increased tolerance level for glyphosate residues on cotton gin byproducts (from 175 to 210 ppm), higher application rates, and corresponding label changes.[16]

DuPont-Pioneer's Optimum GAT soybeans and corn contain a new mechanism rendering plants resistant to glyphosate.[17] GAT stands for glyphosate acetyltransferase, an enzyme that inactivates glyphosate by adding an acetyl group to it. One report by DuPont scientists suggests that GAT corn may survive six times the normal dose of glyphosate "with no adverse symptoms."[18] This would presumably permit higher doses of glyphosate, if necessary changes in glyphosate herbicide labels and tolerance levels were requested and approved by the EPA.

In a patent filing, DuPont-Pioneer proposes to "stack" GAT with one or both of Monsanto's mechanisms of glyphosate-resistance (CP4 EPSPS and GOX [glyphosate oxidoreductase]) in order to enhance tolerance to glyphosate and enable applications of higher rates to control increasingly resistant weeds.[19]

A second patent issued to DuPont-Pioneer contains two examples of glyphosate application to soybeans incorporating dual glyphosate resistance comprising both DuPont-Pioneer's GAT mechanism and Monsanto's CP4 EPSPS mechanism. Glyphosate applications ranged between 3 and 4 pounds of active ingredient per acre per crop year in weed management scenarios outlined in the patent application.[20] These rates per crop year are double to triple the average pounds of glyphosate applied to GE soybeans in 2006 (1.36 pounds per crop year, from NASS annual pesticide survey).

Strine Seed recently petitioned USDA for commercial approval of a new variety of glyphosate-resistant corn,[21]

14 Bennett, D. (2005). "A look at Roundup Ready Flex cotton," *Delta Farm Press*, 2/24/05, http://deltafarmpress.com/news/050224-roundup-flex/.

15 See Monsanto 2008 Technology Use Guide, pdf pages 31 & 34.

16 EPA (2009). "Glyphosate; Pesticide Tolerances," FR Vol. 24, No. 120, June 24, 2009, pp. 29963-29996.

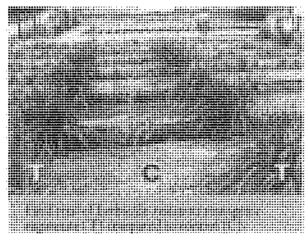
17 Optimum GAT soybeans have been deregulated by the USDA; Optimum GAT corn is under review by the USDA. For fuller discussion of this dual-HR corn, see also: "Comments to USDA APHIS on Environmental Assessment for the Determination of Nonregulated Status for Pioneer Hi-Bred International, Inc. Herbicide Tolerant 98140 Corn," Center for Food Safety, February 6, 2009, http://www.centerforfoodsafety.org/pubs/CFS%20comments%20on%20Pioneer%20HT%2098140%20corn%20EA_final_2_6_09-FINAL.pdf.

18 Castle et al (2004). "Discovery and directed evolution of a glyphosate tolerance gene," *Science* 304: 1151-54. For discussion, see CFS comments cited in last footnote.

19 "Novel Glyphosate-N-Acetyltransferase (GAT) Genes," U.S. Patent 2005/0246798, issued Nov. 3, 2005, assigned to: Verdia, Inc. and Pioneer Hi-Bred International.

20 "Novel Glyphosate-N-Acetyltransferase (GAT) Genes," U.S. Patent Application Publication, Pub. No. US 2009/0011938 A1, January 8, 2009, paragraphs 0152 & 0154.

21 See petition number 09-063-01p at http://www.aphis.usda.gov/brs/not_reg.html.



though it is unclear whether it has enhanced glyphosate tolerance. A biotech startup company in North Carolina, Athenix, is developing a bacterial gene to confer enhanced glyphosate tolerance in multiple crops.[22]

The higher glyphosate application rates made possible by and expected with these new, enhanced glyphosate-resistant crops will almost certainly accelerate the evolution and spread of resistant weed populations. The only viable alternative for conventional farmers to delay the unraveling of RR technology, whether enhanced or not, is to diversify their weed management tactics to include more tillage, altered crop rotations, the planting of cover crops, and more reliance on alternative herbicide modes of action.

Crops Resistant to Multiple Herbicides

The third approach being employed by industry is to develop crops that are resistant to more than one herbicide. Since there are relatively few new herbicides in the development pipeline, this strategy requires companies to engineer resistance to older and often higher-risk herbicides like 2,4-D, paraquat, and dicamba. A review of the scientific literature, the farm press, and petitions for deregulation of herbicide-tolerant crop varieties pending at the USDA shows that the industry is investing heavily in the development of crops with resistance to multiple herbicides.

DuPont-Pioneer's Optimum GAT soybeans and corn combine resistance to glyphosate with resistance to herbicides that inhibit the acetolactate synthase (ALS) enzyme (ALS inhibitors). Optimum GAT crop technology does not seem a promising approach in that it combines resistance to the two classes of herbicides (glyphosate and ALS inhibitors) to which weeds have already developed the most extensive resistance (see Figure 2.4). BASF has also developed ALS inhibitor-resistant soybeans,[23] which will likely also be "stacked" with resistance to glyphosate in the context of a Monsanto-BASF joint-licensing agreement (see below).

From an environmental and human health perspective, the most troubling new resistance traits will allow the use of relatively inexpensive, but toxic herbicides that have not been used widely in corn, soybean, and cotton production for many years because of the initial efficacy of glyphosate in the RR system. In collaboration with the University of Nebraska, Monsanto has developed soybeans that are tolerant to the chlorophenoxy herbicide dicamba.[24] These dicamba-tolerant soybeans are to be stacked with resistance to glyphosate in collaboration with BASF, the largest producer of dicamba.[25] Dicamba-resistant corn and cotton are also under development, with potential triple-stacking of herbicide tolerance to dicamba, glyphosate, and glufosinate.[26]

Dow AgroSciences recently petitioned USDA for commercial approval of a GE-corn variety resistant to a second chlorophenoxy herbicide – 2,4-D, a component of the Vietnam War defoliant Agent Orange. This 2,4-D-resistant corn will be stacked with resistance to aryloxyphenoxypropionate grass herbicides of the ACCase

22 Service, R.F. (2008). "A growing threat down on the farm," *Science* 316: 1114-1117.

23 See USDA petition #09-015-01p. http://www.aphis.usda.gov/brs/not_reg.html

24 Behrens, M.R. et al (2008). "Dicamba resistance: enlarging and preserving biotechnology-based weed management strategies," *Science* 316: 1185-1188; Service, R.F. (2008). "A growing threat down on the farm," *Science* 316: 1114-1117.

25 Monsanto (2009). "BASF and Monsanto formalize agreement to develop dicamba-based formulation technologies," Press Release, Jan. 20, 2009, http://monsanto.mediaroom.com/index.php?s=43&item=683

26 Robinson, E. (2008). "Weed control growing much more complex, new tools coming," *Delta Farm Press*, March 27, 2008. http://deltafarmpress.com/cotton/weed-control-0327/index.html.

inhibitor class.[27] Dow projects introduction of this dual herbicide-resistant corn in 2012, and a corresponding soybean variety in 2013 or 2014.[28]

Finally, Monsanto and Dow are collaborating to produce "SmartStax" corn, which combines resistance to glyphosate and glufosinate, together with six *Bt* insecticidal toxins.[29]

Moreover, the multiple HT crops described above are just the tip of the iceberg. The major players in the industry have discovered or developed at least 12 genes conferring resistance to most major classes of herbicides.[30] One scenario for the future of biotech crops is provided by a 2009 patent granted to DuPont-Pioneer, describing a single plant that is tolerant to at least two, three, four, five, six, or seven or more different herbicide families of chemistry, encompassing dozens to hundreds of individual herbicide products.[31]

The rationale stated in patent applications and other seed industry documents supporting the development of multiple herbicide-resistant crops is that they will provide farmers new options to deal not just with resistant weeds, but also volunteer plants in a subsequent crop season that also happen to be herbicide tolerant. For instance, glyphosate-resistant weeds and RR corn in a soybean field planted to a variety with dual tolerance to glyphosate and ALS inhibitors could be treated with an over-the-top application of an ALS inhibitor. Likewise, Dow's dual-tolerant corn could be sprayed directly with 2,4-D to control weeds or soybeans resistant to glyphosate, and perhaps other herbicides.

Managing resistant weeds triggered by GE crops by developing new varieties tolerant of multiple herbicides is

27 See petition number 09-233-01p at http://www.aphis.usda.gov/brs/not_reg.html.

28 Dow (2007). "Dow AgroSciences reveals progress on new herbicide tolerance trait," August 28, 2007. http://www.dowagro.com/newsroom/corporatenews/2007/20070828a.htm.

29 http://www.monsanto.com/pdf/investors/2007/09-14-07.pdf.

30 Green et al (2007). "New multiple-herbicide crop resistance and formulation technology to augment the utility of glyphosate," *Pest Management Science* 64(4): 332-9, Table 1.

31 Use of the word "type" in this context refers to a herbicide mode of action that might encompass a dozen or more registered active ingredients, and hundreds (even thousands) of products. "Novel Glyphosate-N-Acetyltransferase (GAT) Genes," U.S. Patent Application Publication, Pub. No. US 2009/0011938 A1, January 8, 2009, paragraph 33.

appealing to biotech seed companies, because each herbicide-tolerant trait qualifies the patent holder for a technology fee premium. Progress down this road, however, will draw farmers onto an increasingly costly herbicide treadmill that will erode net farm-level returns and pose significant new public health and environmental risks.

Plus, it likely won't work for long, if at all. Weed biotypes that are resistant to two or three different herbicide modes of action, and literally dozens of herbicide products, are already common. Weeds resistant to glyphosate, ALS inhibitors, or both comprise by far the majority of herbicide-resistant weeds, as measured by both acreage infested and number of resistant biotypes.[32]

Multiple-herbicide-resistant crops will also facilitate more frequent applications of 2,4-D, paraquat, and dicamba, as well as higher rates of application. The two phenoxy herbicides, 2,4-D and dicamba, have been linked to reproductive problems and birth defects in the Midwest, and pose significantly higher risks to a range of organisms than most other contemporary herbicides.[33] Paraquat is a known risk factor for Alzheimer's disease, Parkinson's disease, and other neurological diseases of aging.[34]

Already, and before the introduction of any 2,4-D resistant crops, the spread of glyphosate resistant weeds has markedly increased 2,4-D use. NASS data show 2,4-D applications on soybeans rising from 1.73 million pounds in 2005 to 3.67 million pounds in 2006, a 112% increase. In Lonisiana in 2006, soybean farmers sprayed 36% of their acres with paraquat, 19% with 2,4-D, and applied 2.3 applications of glyphosate to 87% of planted acres.

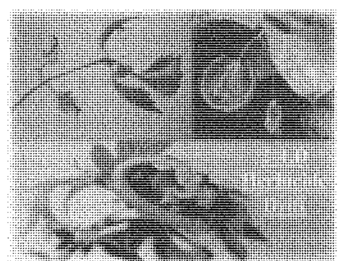
32 For details, see the Weed Science Society of America's "International Survey of Resistant Weeds," http://www.weedscience.org.

33 For an excellent review of the extensive literature on phenoxy herbicides and reproductive problems, see Theo Colborn and Lynn Carroll, "Pesticides, Sexual Development, Reproduction and Fertility: Current Perspective and Future Direction," *Human and Ecological Risk Assessments*, Vol. 13, pages 1078-1110, 2007. On dicamba and birth defects, see Weselak, M. et al., "Pre- and post-conception pesticide exposure and risk of birth defects in an Ontario farm population," *Reproductive Biology*, Vol. 24, Issue 4, August, 2008.

34 Landrigan, P. et al., "Early Environmental Origins of Neurological Disease in Later Life," *Environmental Health Perspectives*, Vol. 113, Num. 9, September 2005.

In summary, glyphosate-resistant crops were rapidly adopted by farmers, who were encouraged to rely exclusively on glyphosate for weed control. Farmers were assured by experts that resistant weeds would never be extensive or difficult to control. Voluntary resistance management guidelines weakly advanced by Syngenta, Monsanto, and others have largely failed, while federal regulators have done essentially nothing to stem the rapid emergence of resistant weeds.

Now that glyphosate-resistant weeds infest millions of acres of cropland and are threatening the viability of the RR system, the industry is proposing "solutions" that are, in truth, technical fixes that are almost certain to make matters worse by creating a greater number of weeds resistant to multiple herbicides. It is also inevitable that there will be further, significant increases in herbicide use, including relatively more toxic herbicides like 2,4-D, dicamba, and paraquat.



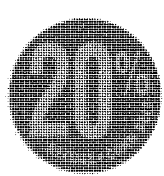
Increased use of chlorophenoxy herbicides will also lead to much more serious and frequent problems with off-target movement of herbicides and damage to crops, shrubs, and other valuable vegetation. Not only are these herbicides prone to drift during application, they also re-volatilize after application under certain weather conditions. The heat of the sun can transform these herbicides back into vapor phase, allowing them to float on the wind and come into contact with non-target plants, such as the wheat or alfalfa in a neighbor's field, or roses in a garden. At low doses, susceptible plants usually do not die, but often suffer harm to their reproductive functions. Pollen and nectar sources for bees and habitat for beneficial insects can collapse due to movement of dicamba into hedgerows and uncultivated land.

Some high-value crops like grapes and tomatoes can be damaged by chlorophenoxy herbicide drift at levels that are essentially undetectable. Factoring this often hidden and always difficult to diagnose damage into the GE crop cost-benefit equation is going to be a major challenge.

Avoiding damage in crop fields from off-target movement and carryover of herbicides is one reason the biotechnology industry is moving toward coupling resistance to glyphosate with resistance to chlorophenoxy and other herbicide modes of action. In fact, some have already advanced the troubling proposition that farmers should purchase chlorophenoxy-resistance traits precisely in order to defend their crops against drift and revolatilization, problems that will be greatly exacerbated if the industry aggressively markets corn, soybean, and cotton varieties engineered for resistance to these herbicides.[35]

C. Resistance Management Still Key in Sustaining *Bt* Crop Efficacy

The future of *Bt* crops is brighter than the future of RR crops. Unlike glyphosate, *Bt* was recognized from the beginning as a valuable, relatively benign insecticide whose continued efficacy required government action to protect against the evolution of resistant insects. As a result, the EPA established programs to preserve the efficacy of *Bt* toxins through the use of refuges for susceptible insect populations and close monitoring of pest populations.

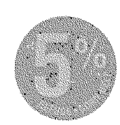


The program has been successful, especially in the case of *Bt* cotton. The attention focused by university entomologists on resistance management, the mandatory resistance management plans imposed by the EPA, and the introduction of Bollgard II cotton that expresses two *Bt* toxins have proven effective, thus far, in delaying the emergence of resistance in cotton pests in most regions.

However, the discovery of several *Bt*-resistant populations of bollworms in Mississippi and Arkansas between 2003 and 2006 by Dr. Bruce Tabashnik and colleagues stands as a reminder that *Bt* resistance must be closely monitored and aggressively managed.

History, too, suggests that continued diligence in cotton *Bt* resistance management is warranted. Since the 1950s, it has taken 10-15 years for key cotton insects to develop resistance to each new type of insecticide applied to control them. This cycle began with the organochlorines from the early 1960s to mid-1970s, and then repeated itself with the carbamates in the 1970s and 1980s and the synthetic pyrethroids in the 1980s and 1990s. The *Bt* cotton varieties have been in use for about 10 years. Researchers have recently shown that cross-resistance can develop in some cotton insect pests to the two *Bt* toxins in Bollgard II varieties.[36] As a result, prudence dictates waiting a few more years before determining whether contemporary resistance management plans are excessive.

Bt corn also remains highly effective for control of ECBs and SWCBs, but is being used in ways that impose significant selection pressure on insect populations. Unfortunately, the industry has convinced the EPA to relax resistance management requirements applicable to recently approved, stacked *Bt* corn varieties expressing two or more modes of action for ECB/SWCB control.



The industry has also asked for reduced resistance management requirements for corn hybrids expressing *Bt* for control of the CRW, an insect notorious for its ability to develop resistance.[37] Scientists convened by the EPA to assess future CRW resistance management plans questioned the science supporting such requests by industry to relax

35 Charles, G, et al (2007). "Tolerance of cotton expressing a 2,4-D detoxification gene to 2,4-D applied in the field," *Australian Journal of Agricultural Research* 58(8): 780–787.

36 Tabashnik, B. et al., 2009. "Asymmerical cross-resistance between *Bt* toxins Cry 1Ac and Cry2Ab in pink bollworm," *Proceedings of the National Academy of Sciences*, www.pnas.org/cgi/doi/10.1073/pnas.0901351106.

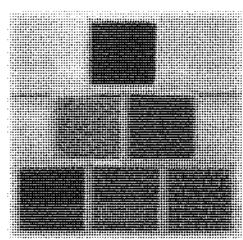
37 The CRW is resistant to insecticide active ingredients in nearly all major insecticide families of chemistry. In addition, the corn rootworm is the first and only insect known to have developed resistance to crop rotations. The western CRW is listed as resistant to 11 insecticides in four families of chemistry in the Arthropod Pesticide Resistance Database at Michigan State University. Details on western CRW resistance are at http://www.pesticideresistance.org/search/12/0/558/0/

resistance management provisions,[38] but the requests were nevertheless approved.

D. Why the Dramatic Increase in the Number of Toxins Needed to Grow Corn?

Another way of looking at pesticide dependence is to track the number rather than the amount of insecticides used on a crop. The combination of nicotinyl and other insecticide seed treatments and the increasing number of toxins in stacked *Bt* corn varieties represents a stunning increase in the number of different pesticidal toxins now being used to bring the nation's corn crop to harvest.

Eight-stack corn hybrids will be planted in 2010 expressing three different *Bt* toxins for control of the ECB/SWCB, and three more to control CRWs – a total of six *Bt* toxins. The seeds will be coated with two insecticides, including one nicotinyl insecticide that will move systemically throughout the tissues of the corn plant. A portion of the acres planted to these varieties will still be treated with one or more conventional corn insecticides.



Accordingly, nine or more chemicals will be used to manage corn insects on many fields in 2010. But on other conventional and organic farms, millions of acres of corn will receive no insecticide, and several million more, just a seed treatment. Traditionally, about two-thirds of corn acres have not required an insecticide spray application.

38 A summary of the EPA Scientific Advisory Panel's comments in February, 2009 on this topic has been prepared by Dr. Mike Gray, "Scientific Advisory Panel Report on Pioneer's Optimum AcreMax Seed Mix Refuge (Refuge-in-a-bag) Request Available On-Line," *The Bulletin*, University of Illinois, No. 9, Article 5, May 22, 2009.

E. Stacking Traits Poses New and Poorly Understood Risks

There has been virtually no independent field research on the ecological and food safety implications when widely planted *Bt* corn varieties are simultaneously expressing two, three, or six *Bt* toxins. Current USDA and EPA approvals are based on the assumption that multiple genes producing different *Bt* toxins in corn plants will operate exactly as they do in varieties engineered to produce just a single *Bt* toxin.

Current EPA policy also apparently assumes there are no interactions in GE plants between the novel DNA introduced in the plant, the novel proteins produced in the plant as a result, and the systemic insecticides and fungicides now routinely used as seed treatments.

These are critical assumptions grounded upon very little science, that also require suspension of common sense. If interactions do, in fact, occur under some circumstances, or if the stability of gene expression patterns is reduced as the number of traits engineered into a plant increases, unpleasant surprises will lie ahead. For this reason, the government and industry should pursue deeper understanding of the impacts of multiple-stacked GE traits, and hopefully before hundreds of millions of acres are planted to them.

There is urgent need for more rigorous and independent scientific examination of the unique risks posed by stacked crop varieties. Multiple-trait varieties are already on the market and will gain a much larger share of the market in 2010. Within a few years, single-trait GE varieties will account for only a fraction of GE-planted acres.

Assessment of the risks of multi-trait crops faces a new and deeply troubling obstacle. Because genetically engineered crops are considered inventions under the patent law, patent holders control their use and sale. Patent rights plus market control give the biotechnology industry extraordinary control over the corn, soybean, and cotton seed supply. Through technology agreements that every buyer or user of GE seeds must sign and comply with, the seed industry also controls who can conduct research on GE seeds, what topics receive research attention, and how, and sometimes even whether, the findings of independent scientists can be reported publicly.[39] Under such a system there simply is no way that scientists can objectively assess the risks of new biotechnology crops, including the new stacked varieties.

Compared to 15 years ago when the first GE crop was planted, farmers and the public have, for the most part, lost control over the seed supply. Until public plant breeding programs and seed companies re-emerge that are dedicated to producing conventional seeds, farmers will have to accept and plant what the seed industry chooses to offer, and the public will have to live with considerable uncertainty over the novel food safety and environmental risks posed by these new crops.

For the foreseeable future, this study coufirms that one direct and predictable outcome of the planting of GE corn, soybean, and cotton seed will be steady, annual increases in the pounds of herbicides applied per acre across close to one-half the nation's cultivated cropland base. Farm production costs and environmental and health risks will rise in step with the total pounds of pesticides applied on GE crops.

Vastly expanded use of 2,4-D and other older, relatively more toxic herbicides on fields infested with glyphosate-resistant weeds will increase human and environmental risks, and greatly increase off-target movement of herbicides, in some instances leading to more damage to plants on nearby farms and in neighboring areas.

39 Pollack, A. (2009). "Crop Scientists Say Biotechnology Seed Companies Are Thwarting Research," *New York Times*, Feb. 20, 2009. http://www.nytimes.com/2009/02/20/business/20crop.html?_r=1&emc=eta; Waltz, E. (2009). "Under Wraps," News Feature, *Nature Biotechnology* 27(10): 880-82.

Pigweed threatens Georgia cotton industry
Brad Haire, University of Georgia
South East Farm Press, July 6 2010
http://southeastfarmpress.com/cotton/pigweed-threatens-georgia-cotton-industry-0706/

*"We're talking survival, at least economically speaking, in some areas, because some growers aren't going to survive this." Several years ago, pigweed found the weakness and breached the defense that Georgia cotton growers used to control it. It now threatens to knock them out, or at least the ones who want to make money, says a University of Georgia weed expert.

"It's been devastating in a lot of ways," said Stanley Culpepper, a weed specialist with the UGA College of Agricultural and Environmental Sciences who's taken a lead in fighting the weed in Georgia. "It's without a doubt the largest pest-management problem that any of our agronomic growers are facing, especially our cotton producers."

If not killed early, pigweed - also called Palmer amaranth - can grow as tall as a small shade tree in fields, gobble nutrients away from cotton plants, steal yields and in severe cases make harvest difficult or impossible.

How did we get here?

In 1997, farmers started planting [GM] cotton that was developed to stay healthy when sprayed with glyphosate herbicide, commonly sold under the brand name Roundup. They could spray the herbicide over-the-top of this cotton, killing weeds like pigweed but not the cotton. Virtually all Georgia cotton grown now is "Roundup Ready" because it saves farmers time and money. But relying on one tool to do the job can lead to problems.

In 2005, the first case of pigweed resistant to glyphosate was confirmed in middle Georgia, the first confirmed case in the world. At the time, it was localized to a few fields on about 500 acres. The resistance has since spread across 52 counties, infesting more than 1 million acres. Within the next year or two, Culpepper said, it will likely be in every agronomic county in the state. It's also confirmed in most other Southeastern states.

Glyphosate didn't cause pigweed to change genetically or to become a resistant mutant, he said. All it took was a few weed plants in a field or area to be genetically different - in this case, resistant to glyphosate. The resistant ones survived to reproduce.

Pigweed is dioecious, meaning it needs separate male and female plants to reproduce. And it can reproduce a lot. The male produces the pollen. The female produces the seed. The resistant trait is passed through pollen, which can survive in the air and travel as far as a mile. One female plant can produce between 500,000 to 1 million seeds.

Economic survival?

According to a survey last year, half of Georgia's 1 million acres of cotton was weeded by hand for pigweed, something not normally done, costing $11 million. Growers went from spending $25 per acre to control weeds in cotton a few years ago to spending $60 to $100 per acre now.

"We're talking survival, at least economically speaking, in some areas" Culpepper said, "because some growers aren't going to survive this."

Growers in middle Georgia who've battled the resistance for several years now are aggressively attacking the weed. Growers in other regions need to get on board. "If they don't have resistance yet they will," he said.

The key is diversity, or using more than one tool to fight invaders. Herbicides still provide good control, he said, but they must be applied at the right time and, if possible, under the right conditions. Growers, too, must reduce the number of pigweed seeds in their fields.

"Herbicides alone often will not provide adequate control. An integrated program must be developed to reduce the amount of Palmer that actually emerges," Culpepper said. "If it (pigweed) doesn't come up, we don't have to kill it."

Deeply tilling the soil in a field can reduce pigweed seed germination by as much as 50 percent in that field. Using heavy cover crops like rye to provide a thick mat between plant rows can also reduce germination by as much as 50 percent and give cotton plants a competitive edge over the weed. The combination of deep tillage and cover crops in a field can reduce pigweed seed germination by as much as 80 percent. All of this helps, he said, but it won't knock the giant out.

The situation is bleak, he said, but the cotton industry, chemical companies and researchers are responding and trying to catch up with pigweed.

"It won't be tomorrow or even next year, but we have some new technology coming.

I'm certainly more optimistic. We've got some good options we're testing now," Culpepper said. "But we're going to have to change how we've handled this pest in the past. If growers don't, they simply won't be growing cotton.

http://deltafarmpress.com/cotton/resistant-weeds-0202/

Changing tactics for resistant weeds

Feb 1, 2010 2:56 PM, By Ron Smith, Farm Press Editorial Staff

Herbicide-resistant weeds threaten farmers across the Cotton Belt and some are already facing weed populations that exact heavy yield losses along with reductions in fiber quality.

Using several herbicides with different modes of action will be the key to managing these resistant weed populations, said University of Tennessee weed specialist Larry Steckel during the annual Cotton Consultants Conference, which kicked off the recent Beltwide Cotton Conferences, held this year in New Orleans.

Steckel said herbicide resistance resulted from use of a single herbicide to control weeds — primarily in cotton, soybeans and corn — and that moving away from a one-product control strategy with burndown applications will be essential for weed control.

"Traditionally, growers used three herbicides for burndown treatments," Steckel said. "Gramoxone, glyphosate and 2,4-D were widely used in the late 1980s and 1990s." Roundup (glyphosate) came on in the late 1990s as the price went down. Gramoxone price remained about the same, he said. "Some farmers kept 2,4-D in the mix."

But with Roundup Ready crops, glyphosate use increased significantly and the reliance on one mode of action paved the way for weed population shifts and herbicide resistance. Resistant marestail first showed up in the Delta and Southeast as farmers "used Roundup almost exclusively in the late 1990s."

But resistance did not happen in a vacuum. Departments of transportation and municipalities also used Roundup and that helped select for resistant weeds. "We see a lot of resistant horseweed in cities," Steckel said.

Weed control programs in many areas other than farming were using one herbicide and selecting for resistance and that "ramped up resistance issues."

Steckel said the problem is compounded by the presence of several ALS-resistant weeds. "We will have to deal with that, too," he said.

For most cotton farmers, horseweed is the primary concern. "But we've also seen glyphosate-resistant Italian ryegrass in Tennessee. Ryegrass has always been hard to control with Roundup."

He said other concerns include primrose, bluegrass, Palmer amaranth, and giant ragweed.

Marestail seems to be the biggest threat. "It was identified in Tennessee in 2001, and we found a bad field in 2003. It got worse. Population in one field showed 30 to 40 horseweed plants per square foot."

He said the weed is persistent. "It has a very long germination period, 10 months, with most emerging in the fall but with another bump in April and into May. Weeds that germinate in the fall develop a strong root system and are harder to control."

Management is possible, he said. "In early February, fall-germinated marestail has not gotten large, and we can hit it with a burndown and see fewer control issues." But growers need a multi-pronged approach. Steckel recommends Clarity with glyphosate. "That works best for us," he said. "Tennessee farmers do not use 2,4-D much. It's not as effective as Dicamba. Ignite works well if we have enough heat, about 80 degrees. It's not as effective in cool weather."

He said Roundup and Clarity early followed by Gramoxone and Caparol behind the planter is a good weed management program.

But not all herbicides, even the best ones, work under all conditions. "In 2006 and 2007, we used dicamba on a large (horseweed) population and struggled to get control. But we had a dry spring and dicamba is taken up through foliage and roots and during the drought we had less uptake from roots."

He said a higher rate may have improved control.

Steckel said a new product from BASF, Sharpen, also holds promise. "It's good on marestail and provides two weeks of residual activity. It's labeled for cotton, corn and soybeans."

He said controlling glyphosate-resistant Palmer pigweed may require something like Prowl to aid the burndown. "We have developed weed biotypes that escape burndown herbicides," he said.

"Giant ragweed has shown glyphosate resistance." It's also changed habits. "Giant ragweed typically started to emerge in February and was done by April," Steckel said. "We were home free after that. Now, we're seeing an extended window of germination, a lot of emergence into June. And that late flush is very competitive and our burndown efficacy has changed. We will need to switch herbicides to manage weed escapes in season."

He said ryegrass is another emerging problem. Ryegrass typically has been easy to control with several herbicides prior to tillering. "After it matures past two tillers, it's more difficult."

He also said that fields with several species of glyphosate-resistant weeds offer unique management problems. If a field has resistant Palmer pigweed and resistant marestail, growers likely will need two different herbicides for adequate control.

He said crop selection also plays a role in resistance management. "Soybeans are more competitive with horseweed than is cotton," he said.

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http://sl.farmonline.com.au/news/nationalrural/grains-and-cropping/general/glyphosate-resistance-warning/1734388.aspx

Glyphosate resistance warning

MATT CAWOOD
01 Feb, 2010 11:00 AM

A NEW form of glyphosate resistance has prompted a warning that the herbicide has "become as important for reliable global food production as penicillin is for battling disease".

A vigorous weed of cotton fields in the south-east United States, Palmer amaranth, has been found capable of resisting the effects of glyphosate through "gene amplification", the third type of resistance mechanism now discovered, and one that has rung alarm bells with researchers.

Winthrop Professor at the University of Western Australia, Stephen Powles, wrote in an introduction to the latest Proceedings of the National Academy of Science (PNAS) that massive adoption of transgenic glyphosate-resistant crops has meant "excessive reliance" on glyphosate for weed control.

"In evolutionary terms, widespread and persistent glyphosate use without diversity in weed control practices is a strong selection pressure for weeds able to survive glyphosate," Professor Powles wrote.

Plant genes that endow glyphosate resistance are very rare, but the huge volumes of the chemical sprayed on the world's crops is helping those genes come to the fore.

"Glyphosate resistance evolution is a major adverse development because glyphosate is a one in a 100-year discovery that is as important for reliable global food production as penicillin is for battling disease."

Glyphosate acts by inhibiting a plant enzyme, EPSPS.

Researchers had previously found two modes of glyphosate resistance: a mutation of EPSPS that is not affected by the chemical, or more usually, a single gene mutation that restricts movement of glyphosate in the plant, preventing it from reaching EPSPS in toxic levels.

A scientific team led by Dr Todd Gaines, formerly of Colorado State University but now working on the Western Australia Herbicide Resistance Initiative (WAHRI), has now found that Palmer amaranth can genetically multiply its output of EPSPS.

"It acts like a sponge to absorb the normal rate of glyphosate that we apply to these plants, and so they survive," Dr Gaines said.

"What's really interesting is the capacity of these plants to evolve extra gene copies. It would certainly be reasonable to expect other plants to exhibit this same behaviour."

Professor Powles noted that insects have been known to amplify genes that detoxify insecticides, but in this case Palmers amaranth is amplifying the target gene itself to produce something like 20 times the quantity of the enzyme that normal applications of glyphosate shut down.

"With this development, we have an even stronger basis to urge world agriculture to use glyphosate-resistant crop technology more wisely than has occurred until now," Professor Powles said in his PNAS commentary.

"Indeed, the precious herbicide glyphosate is at risk of being driven into redundancy because of overuse without diversity in weed control practices."

"It is not an exaggeration to state that the potential loss of glyphosate to signiÞcant areas of world cropping is a threat to global food production. To avert this situation requires that glyphosate be used more judiciously and with more diversity than is currently the case."

The International Service for the Acquisition of Agri-Biotech Applications (ISAAA) reported that in 2008, "...herbicide tolerance deployed in soybean, maize, canola, cotton and alfalfa [lucerne] occupied 63 per cent or 79 million hectares of the global biotech area of 125 million hectares".

Dr Gaines said most of that inbuilt resistance was to glyphosate.

ISAAA also noted that by 2008, the world had planted a cumulative 800 million hectares, or two billion acres, of biotech crops.

Dr Gaines paper on gene amplification appeared with Professor Powles's commentary in the January 2010 edition of PNAS.

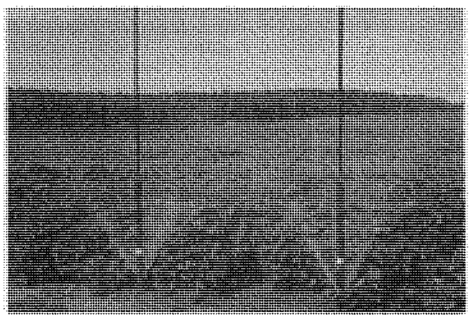
http://southwestfarmpress.com/cotton/cotton-management-0201/

Managing weed, insect resistance in cotton critical

Feb 1, 2010 11:02 AM, By Roy Roberson, Farm Press Editorial Staff

Staying a step or two ahead of insect and weed resistance problems is a key to bringing cotton acreage back in the Southeast and Delta, say leading researchers.

Managing resistant insects and weeds goes well beyond being important, say Roger Leonard and Stanley Culpepper — it is essential from both economic and production standpoints to continue growing cotton in the South.



MANAGING GLYPHOSATE RESISTANCE under irrigation will require different strategies, says UGA Scientist Stanley Culpepper.

Leonard, an entomologist at LSU's Ag Center says one of the first glimpses of insect resistance seen by farmers in the Southeast was pyrethroid resistant budworm and bollworm. This was far from an unmanageable problem, but opened the eyes of entomologists as to future problems with advanced insecticide technology back in the 1970s.

"We didn't know exactly what to make of the problem back then, but all of us in the cotton pest management business saw fields where pyrethroids didn't work," Leonard said, speaking at the recent Beltwide Cotton Conference in New Orleans.

When Bollgard came onto the market, the problem of pyrethroid-resistant insects highlighted the efficiency of these new products.

Before Bt cotton, growers in the Mid-South routinely sprayed an average of 4-6 times and up to 10 times for the tobacco budworm-bollworm complex. The early Bt products cut sprays by 50 percent. The new generation of Bollgard and Widestrike products will likely cut another 50 percent of insecticide use. This technology still won't eliminate the need for insecticides in some fields, but it will significantly reduce the amount of conventional materials used by cotton farmers, Leonard says.

"Despite the success of these products in managing the bollworm-budworm complex, they do not make cotton insect-free. In fact, these materials accentuate the need for a well-trained professional to scout for secondary insects not controlled by Bt technology."

Rotating insecticides is critical, Leonard stresses, to maintain a high level of efficacy and a relatively low cost.

Culpepper, a weed scientist at the University of Georgia, also speaking at the Beltwide meeting, says the reason for the dramatic increase in use of glyphosate-based weed management programs throughout the South is primarily simplicity of using these products, combined with their high level of efficacy in controlling a wide spectrum of weeds.

From 1997 to 2001 Roundup Ready cotton went from zero to 67 percent in the South. By 2006, at least 97 percent of the cotton in the Southeast was planted to Roundup Ready varieties.

In 2000, the first case of glyphosate resistant horseweed was confirmed, and this was further confirmed in cotton in 2001. Horseweed has not been a severe problem in cotton for the most part, but it did open the eyes of weed scientists across the country that there were changes occurring in weed management from glyphosate-based systems.

"Despite the growing evidence we would likely have future problems with glyphosate-resistant weeds, use of the technology continued to spread rapidly. Cotton acreage in the Mid-South and Southeast continued to increase well into the 2000s.

"In 2004, the first case of glyphosate resistance was documented in Palmer amaranth pigweed in Georgia. Growers who have faced this problem can attest that all weeds are not created equal, Culpepper says.

"By 2006, resistance was confirmed in five states and by 2009 glyphosate resistant pigweed was confirmed in 120 counties in eight states, and I'm soon to add another 10-12 counties in Georgia," the weed scientist adds.

"We can no longer do as we did from 1999 to 2004 — rely primarily on glyphosate for control of Palmer amaranth — and a growing number of other weed species," Culpepper says. "Those days are ending for many growers in the Southeast and they are ending very, very rapidly," he adds.

"When a grower has multiple herbicide resistance in a weed species like Palmer pigweed, he's got a real problem. When you lose two or more families of herbicides to resistance, for example ALS and glyphosate resistance, you to no longer have a reliable topical herbicide to control Palmer amaranth — that is a challenge.

"In Georgia, if you come to me with a weed problem, other than Palmer amaranth, I will have an answer for you — quickly. If you come to me with glyphosate resistant Palmer amaranth, I need to ask you a dozen or so questions before I can begin to give you a solution to your problem," Culpepper says.

"Irrigation is a big question. If you have it, we have some options we don't have on dryland cotton. If you have dryland cotton, we have some different options if you no-till versus using conventional-tillage. Palmer amaranth that cannot be controlled by glyphosate is just a challenging pest to manage.

"You can be the best farmer on the planet and you can go out and spend more than $50 per acre for weed control and still not be able to pick your cotton because you simply cannot manage resistant pigweed," Culpepper stresses.

"My family farms, my two best friends in the world farm — I think farmers are the greatest people on earth. Still, my family, my friends and most of the farmers I know simply aren't prepared for the impact Palmer amaranth has had and will have on many, many more acres of cotton in the South," he adds.

"To win against this pest we are going to have to develop integrated weed management strategies that we didn't even dream about back when we were openly embracing this new Roundup Ready technology."

"For example, a grower can go out and spend the $50-plus in herbicides and unless he or she can make it rain, they are very likely to lose against Palmer amaranth. If the grower integrates a deep tillage program and turns enough weed seed under ground — and it appears at 18 inches below the surface Palmer amaranth is killed off in large numbers — the $50 herbicide investment has a much better chance of working.

"For conservation-tillage growers, you can get the same kind of benefit from planting a rye cover crop to reduce the number of Palmer amaranth seed that emerge. These are the types of things growers don't want to do, but must do to be competitive with Palmer amaranth.

"Deep tillage and a rye cover crop together work better than either works alone, but too few farmers either don't have the equipment to do both or are not willing to switch from one tillage system to another.

"To be successful, these integrated programs still must include herbicides. Some ask, "why use a herbicide, if I only get a low percentage of weeds controlled. The answer is simple, without herbicides, especially residual herbicides in the system, there is no chance for success," Culpepper explains.

"In a dryland, conservation-tillage system with glyphosate resistance, an Ignite-based herbicide program will work better than a glyphosate-based program. Ignite-based systems are highly time sensitive — you just don't have the same window of opportunity for killing pigweed with Ignite that you had with glyphosate. Growers, in many cases, have to learn how to use Ignite — it is a different herbicide than glyphosate," Culpepper says.

Leonard and Culpepper agree the tools are there to manage insect and weed resistance problems, but it will take some different thinking to put these tools to best use in different crop production systems.

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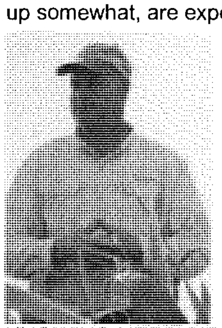
http://southeastfarmpress.com/soybeans/weed-control-0202/

Herbicide family knowledge key to weed control

Feb 1, 2010 3:12 PM, By Roy Roberson, Farm Press Editorial Staff

Rotating herbicides and tank-mixing older herbicides with newer chemistry to avoid herbicide resistance problems will require extensive knowledge of herbicide families and modes of action.

Farmers in the Southeast took advantage of low global stocks of soybeans and subsequently good prices to plant more beans in 2009. Similar planting levels, possibly up somewhat, are expected for 2010.



KNOWING HERBICIDE families will be increasingly important in the future, says North Carolina State Researcher David Jordan.

For many areas of the Southeast, including soybean production areas throughout the Carolinas and into Virginia, herbicide resistant weeds continue to be an ongoing problem that weed scientists project will get worse unless farmers begin to make management decisions geared toward solving the problem.

Timeliness has never gone out of vogue in weed control, **but it will become even more important in 2010 as growers see more and weed species with tolerance to multiple herbicides.**

According to North Carolina State Agronomist David Jordan, **the timeliness issue is critical in the Tar Heel State as more and more growers revert to older chemistry to fight weeds resistant to glyphosate, ALS and PPO chemistry.**

"When we first started using glyphosate-based systems a decade or so ago there was a lot of flexibility on how big you could let a weed get before treating it. Glyphosate resistance changed that window of opportunity and when having to move to some of the older chemistry and new chemistry, like Ignite, you have to be more timely," Jordan says.

Palmer pigweed is a particular challenge, especially because of the 'super weed's' ability to develop resistance to glyphosate.

If a grower lets pigweed get to 12-15 inches tall, it will be a real challenge for Ignite, any of the PPO inhibitors or any of the older ALS-inhibiting herbicides. Even pigweed at 8-10 inches tall is borderline for these materials. On the other hand, 3-4 inch tall pigweed are still manageable with Cobra, Blazer or some of the other PPO-based herbicide.

Once resistance is established in a field, it is very difficult to eliminate it. There are ways to manage the problem and reduce the risk of getting herbicide resistance, and **the best strategy is to rotate chemistry.**

In soybeans, Jordan conducted a series of tests to look at two ways of reducing the threat of resistance and managing it when it occurs.

The first way is to put out a pre-emergence or incorporated herbicide, depending on what crop is grown and how it is grown. Most folks don't want to do this — it's time consuming, expensive and depends a lot on getting moisture at the right time.

Jordan put together a test using the major labeled soil-applied herbicides — some of which were popular 12-15 years ago, but may have not been used much the past decade. With each of these herbicide systems, he came back with Flexstar, compared to glyphosate.

The other approach to get multiple modes of action is to tank-mix other herbicides in a glyphosate-based system. Despite the much publicized resistance problems now facing glyphosate herbicides, this chemistry is still very effective on a wide range of weeds.

In on-farm testing near Elizabeth City, N.C., the North Carolina State researcher got excellent weed control from several different herbicide systems.

Prowl at two pints per acre, applied June 20, followed by Flexstar at 1.25 pounds per acre applied on July 15 provided outstanding weed control.

Prefix, a combination of Reflex and Dual has become a popular treatment on soybeans in the upper Southeast. In Jordan's on-farm test in northeast North Carolina, Prefix provided good weed control without Flexstar or glyphosate. Jordan says that under other growing conditions or soil types or weather conditions, the same treatment may not work so well. He urges growers to look at comprehensive statewide tests before making decision on which materials to use.

"In some cases you get good rainfall and good activation of these pre-treatments and get fast growing soybeans up quickly, you may not need post-applied herbicides. In other cases when conditions aren't so ideal, you are going to need one or more of these materials," Jordan cautions.

Authority is another material that did well in the North Carolina test. It was applied pre-emerge at 12 ounces per acre on June 20. This herbicide contains an old familiar herbicide — metrabuzin, plus a different, newer chemistry sulfentrazone.

Authority MTZ controls a variety of broadleaves that have exhibited resistance to glyphosate and/or ALS herbicides. In addition, when used as part of a fall burndown program, it provides residual control of a number of small-seeded broadleaves and winter annual weeds including henbit, chickweed, pigweed, marestail, lambsquarters and waterhemp, according to product manufacturer FMC.

Python and Sencor under the test conditions did a good job, but benefitted from a post-emergence application of Flexstar or glyphosate to clean up. Flumetsulam is the active ingredient in Python and metrabuzin in Sencor, so two different chemistries to fight resistance.

Dual-Magnum at a pint and a half per acre did not do well in the northeast North Carolina grower field and did not provide adequate pigweed control by itself. Valor at 2.2 ounces applied on June 20, plus Flexstar at 22 ounces per acre did a good job, but showed some crop damage.

Outlook, a chloroacetamide-containing herbicide, is another option that did well in Jordan's on-farm test. Chloroacetamide herbicides such as Outlook control susceptible weeds by inhibiting the synthesis of very long-chain fatty acids in the plant, thus preventing root and shoot growth.

Typically, weed seedlings exposed to soil applications of Outlook die before or shortly after they emerge. Outlook, which is a popular herbicide choice in potato production, will not control weeds already emerged.

Envive also did well in the North Carolina test. It contains Valor, thirinuron and disulfuron. Some grass came through in the test, but pigweed control was good. Add glyphosate or Flexstar to the application and Envive provided excellent control of broadleaf weeds.

Envive is a combination of three slightly different modes of action. It is a spring — applied, pre-emergence, herbicide premix that includes chlorimuron (Classic), flumioxazin (Valor), and thifensulfuron (Harmony GT).

Envive is designed to provide some burndown and residual weed control when applied two weeks before planting up to three days after planting (before soybean emergence).

Intro, previously known as Lasso, looked good at three quarts per acre for pigweed control. There was not much need for Flexstar or glyphosate at this particular location in North Carolina.

Jordan says the choice of the older herbicides used in soybeans to diminish glyphosate resistance problems is not as important as using different modes of action. Knowing which of these materials will work best in your particular operation is critical to both optimum performance from the herbicide and optimum crop production.

"In North Carolina, we are beginning to see resistance in PPO inhibitors, like Reflex. Cobra and Blazer. We already have ALS resistance and glyphosate resistance. In some areas of the Midwest they are beginning to see quad resistance — or resistance to four different families of herbicides — in water hemp," Jordan adds.

Knowing families of herbicides and modes of action of herbicides, not trade names, is going to be an ongoing challenge for soybean farmers in the Southeast in 2010 as they struggle to manage an ever-growing weed resistance program.

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http://www.agriculture.com/ag/story.jhtml?storyid=/templatedata/ag/story/data/1264542668567.xml

Reeling from resistance

Weed resistance to glyphosate and other herbicide modes of action increase
Gil Gullickson
Successful Farming magazine Crops Technology Editor
1/26/2010, 3:47 PM CST

Resistance worries

Initially, glyphosate appeared to be taking it on the chin this month at the Pan-American Weed Resistance Conference in Miami.

"My prediction is glyphosate will be driven to redundancy in large parts of North America and South America," says Stephen Powles, professor and director of the Western Australia Herbicide Resistance Initiative at the University of Western Australia.

The culprit? Weed resistance. Currently, biotypes of nine glyphosate-resistant weed species have been confirmed in 20 states.

Into the Bayer CropScience-sponsored conference, though, glyphosate was often praised.

"Glyphosate is the world's greatest herbicide," adds Powles. "It is a one in a 100-year discovery. It is right up there with penicillin for humans in terms of discovery. We should do everything we can to keep it."

Bayer scientists stressed the following tools to preserve glyphosate at the conference:

- **Herbicide diversity.** This will involve rotating herbicide modes of action in a weed management strategy.

- **Crop diversity.** "Changing crops also is one of the basic tools and building blocks for successful integrated weed control," says Harry Strek, who heads integrated weed management and weed resistance biology for Bayer.
- **Cultural practices and field hygiene measures.** This includes factors like planting clean seed and tillage. However, this tool is limited in areas where no-till is predominant, say Bayer officials.

The 'glyphosate belt'

Powles terms the area reaching northward into the Corn Belt down through Alabama and Mississippi as the "Glyphosate Belt.

"In the U.S., when you have you have 70% Roundup Ready corn, 95% Roundup Ready soybeans and 95% Roundup Ready cotton in this area, this (weed resistance) is what happens," he says.

In the South, glyphosate-resistant palmer amaranth -- a member of the pigweed family -- has rendered glyphosate ineffective in many areas. "Through most of the South, with the possible exception of some areas of Alabama and Louisiana, glyphosate is no longer a pigweed herbicide," says Robert Nichols, senior director of agricultural research for Cotton Incorporated.

That's prompted those farmers to search for other alternatives, including pre-emergence herbicides followed by postemergence applications of glufosinate in a LibertyLink system.

"The era of total post weed control is over, and I don't think it's ever coming back," says Larry Steckel, University of Tennessee Extension weeds specialist. So far in the Midwest, glyphosate continues to control weeds fairly well in glyphosate-tolerant systems.

Glyphosate will continue to be the top component of row crop weed control programs, says Mike Owen, Iowa State University Extension weeds specialist.

But unless farmers change management strategies -- such as mixing modes of action and use preemergence herbicides -- glyphosate-resistant weeds will increase.

"Right now, we on the edge of a precipice that we could step off in the next two years," says Owen.

Glyphosate resistance also is occurring in other parts of the world, due to repeated use of the same crop and weed control method, says Powles. "In Australia, it is wheat followed by wheat," he says. "In Argentina, it is Roundup Ready soybeans followed by Roundup Ready soybeans. In terms of weed management, there has been a complete absence of diversity."

Other herbicides impacted by resistance

It's important to note weed resistance impacts other herbicide modes of action as well, such as in cereals.

"There is a predominance of herbicide-resistant weeds in cereals occurring in northern tier states," says Ian Burke, a Washington State University weed scientist. "Most alarming is downy brome resistance to ALS (inhibitor) chemistry."

Hugh Beckie, a weed scientist with the Agriculture and Agri-Food Canada Research Center in Saskatoon, Saskatchewan, notes **there has been an increase in western Canada in multiple-mode of action weed resistance.**

"There has been a surge in ACCase inhibitor plus ALS inhibitor resistant weeds," he says. **"Based on samples growers submitted in the 2008 crop year, there were more cases of multiple resistance than in the previous 11 years combined."**

In Illinois, a "quad stack" of a common waterhemp biotype has been confirmed with resistance to the following modes of action:

- **Triazines (atrazine)**
- **ALS inhibitors (imazethapyr, active ingredient in Pursuit)**
- **PPO inhibitors (sulfentrazone, active ingredient in Authority)**
- **Glyphosate**

Bayer officials stressed weed resistance has not developed to glufosinate (active ingredient in Ignite, used in the LibertyLink system) and HPPD inhibitors (such is **isoxaflutole,** active ingredient in Balance Flexx.) Bayer manufactures herbicides with these action modes.

It's important to note, though, that proper stewardship is important to forestall resistance in all herbicide modes of action. Powles notes that if glufosinate-tolerant systems replaced all current glyphosate-tolerant systems across North and South America, weed resistance would eventually develop to glufosinate.

"We have to recognize that herbicides are precious resources," he says.

He theorized what evolutionist Charles Darwin would have thought if glyphosate was put on the majority of corn, soybean, and cotton acres across half a continent, as it has in the Corn Belt and the South.

"He would have said, "Nature will win'" says Powles.

http://www.agriculture.com/ag/story.jhtml?storyid=/templatedata/ag/story/data/1264524811431.xml

The best way to no weeds is to know weeds

Gil Gullickson
Successful Farming magazine Crops Technology Editor

1/26/2010, 10:48 AM CST

Another 'agronomic practice'

Back in 1996, competitors of Monsanto faced a dilemma regarding Roundup Ready soybean technology.

Farmers liked it. No, they loved it. "First, there was denial, saying it wouldn't happen, there would be yield drag," recalls Michael Heinz, who headed BASF's crop protection division before heading the global Ciba integration team last year.

This concern soon passed. Farmers nixed other soybean herbicides like a runaway bride who left a spurned suitor at the altar.

"A couple years later, we sat together and asked ourselves, Should we exit herbicide research?' " says Heinz. "But if we did that, it would take a long time to get back in the game (if matters changed)."

Matters eventually changed, though slowly. Farmers continued to adopt glyphosate-tolerant systems to the point where they are now used on around 95% soybeans acres and 70% of corn acres.

"Growers thought there would never be any more problem with weeds," says Mike Owen, Iowa State University Extension weed specialist.

Not exactly.

Small cracks initially surfaced in glyphosate's weed control armor. In 2000, University of Delaware weed scientists confirmed a marestail biotype that was resistant to glyphosate. Now, it's estimated glyphosate-resistant marestail infests 5 million U.S. crop acres.

Meanwhile, biotypes of nine weeds in 20 states have been found to be glyphosate-resistant. Several weeds -- such as biotypes of common waterhemp -- resist multiple modes of actions.

All this isn't a knock against glyphosate. Glyphosate's complicated mode of action, no soil residual, and little or no ability by plants to metabolize it make it a low weed-resistance risk. Weeds became resistant much quicker to herbicides with narrower weed spectrums and longer soil residual periods, such as atrazine and ALS inhibitors like Pursuit.

It's just that use over millions of acres for over a decade kicked in the law of the jungle.

"All agronomic practices exert selection pressure," says Owen.

In glyphosate's case, all that was needed was selection of a resistant biotype that may have initially tallied just one in 100 million.

Strategies & tools to consider

The good news?

"Glyphosate is still going to be the number one component of any weed-control program out there," says Owen.

Meanwhile, new technology that will complement glyphosate or provide alternatives to it is coming.

Still, the way you deal with future weeds involves more than new products. Owen cautions against overreliance on any one technology. "Weeds will take every opportunity (to become resistant) to repeated herbicide uses," he says.

Adding another mode of action has another perk in that mixing them up will help forestall weed resistance to all herbicides.

"My crop adviser, Brad Johnson, has cautioned me never to spray glyphosate alone, always have partner with it," says Mike Jordan, Beloit, Kansas. "It will help prevent resistance."

Rethink weed management

You'll also need to rethink how you manage weeds.

"Ultimately, weed control is not the same as weed management," says Aaron Hager, University of Illinois Extension weed specialist.

Weed-free yields at harvest indicate excellent weed control. Yet, this can mask yields that weeds robbed if they weren't killed early in the season.

The switch toward weed management will involve using residual preemergence herbicides. They can protect plants for the first four to six weeks of emergence before post-emergence herbicide application.

Things to consider

Here are strategies, tools and facts to consider as you form a future weed-management plan.

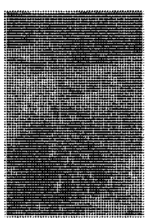
http://southeastfarmpress.com/cotton/herbicide-resistance-0119/

Herbicide resistance finding troublesome

Jan 19, 2010 9:40 AM, By Roy Roberson, Farm Press Editorial Staff

The gene-copying capabilities of Palmer amaranth helps explain the rapid spread of glyphosate resistant pigweed and puts added pressure on farmers to develop resistance management programs for all the crops they grow.

The recent finding of a new mechanism by which Palmer amaranth pigweed develops resistance to or tolerance of glyphosate is big news in the scientific community, but far from good news for farmers in the Southeast.



RESEARCHERS have found a new herbicide resistance mechanism that is less than good news for Southeast growers.

Working with glyphosate resistant pigweed seed from Georgia, researchers at Colorado State University have determined that pigweed have the ability to mass copy the gene that glyphosate attaches to and uses to block a key passageway. Long story short, glyphosate shuts down the plant and rapidly kills it — in non-resistant pigweed.

Veteran Weed Scientist Phil Westra, a professor at Colorado State University says, "Technically what happens is the molecular target of glyphosate in pigweed is the enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS, EC 2.5.1.19). This enzyme is a component of the shikimate pathway. By attaching to the (EPSPS, EC 2.5.1.19) target enzyme , glyphosate is able to shut down the shikimate pathway, rapidly breaking down the plant and killing it.

"The shikimate pathway links metabolism of carbohydrates to biosynthesis of aromatic compounds. The penultimate enzyme of the pathway is the sole target for glyphosate.

"A typical plant will have two copies of the gene. In a glyphosate resistant plant we have found up to 160 copies of the gene that produces the enzyme to which glyphosate attaches," Westra explains.

The pigweed plant pumps out these gene copies, which in effect dilutes glyphosate to the point of being ineffective in controlling these weed pests. "When glyphosate is sprayed on one of these resistant plants, some of the enzyme is tied up, but plenty more is around and not affected by the herbicide," Westra explains.

This occurrence of gene amplification as a herbicide resistance mechanism in a naturally occurring weed population is particularly significant because it could threaten the sustainable use of glyphosate-resistant crop technology, Westra contends.

The molecular trait in pigweed is passed along via pollen. Pollen can easily move it 300-400 feet in a cropping season. Westra says this explains why growers usually see a pigweed or two sticking up in a field one year and the next year have an oval-shaped clump of weeds that may be 20-30 feet across.

This latest discovery of a new mechanism by which herbicide resistance develops adds a new chapter to the overall story of resistance problems that continue to grow for farmers worldwide. Previously, three primary mechanisms were known to produce herbicide resistance in weeds and target plants.

The most commonly occurring mechanism is via an altered target site in which there is mutation for a certain enzyme in a gene. This is the classic mechanism for plant resistance to ALS inhibitors and other urea-based herbicides.

Altered translocation pattern is another less common mechanism. When this occurs in a weed, horseweed is a good example, the herbicide is re-directed to the leaf edges or other areas of the plant where it can do little damage. Growers in the Southeast are becoming all too familiar with glyphosate resistant horse weed.

A third mechanism, common in other parts of the world, but not known in the U.S., occurs when a plant chemically breaks down the herbicide and renders it inactive.

"I don't think we have the final answer on Palmer amaranth resistance. The consensus is that there are two or three mechanisms for resistance. The tests we ran came from seed from Stanley Culpepper in Georgia (weed scientist at the University of Georgia) and these have a high level of resistance. Ken Smith in Arkansas (professor and weed scientist at the University of Arkansas) and Alan York in North Carolina (weed scientist and professor emeritus at N.C. State University) have indicated some of their pigweed may not have the same level of resistance," Westra says.

This new finding accentuates the need for farmers to have a good herbicide resistance avoidance and/or management plan for all crops. Though glyphosate resistance is the biggest newsmaker, it's far from the only herbicide resistance problem faced by farmers.

Knowing the active ingredient and/or mode of action in all herbicides is a basic ingredient of a good crop production plan. Managing crop rotations and rotating herbicide families used in each crop is already common among most successful farmers in the Southeast. The latest scientific revelation as to how glyphosate resistance develops is another good reason to intensify crop and herbicide rotation strategies.

One beneficial side effect of the Colorado State findings is the development of a rapid assay test to determine whether a pigweed plant is glyphosate resistant. Building on an earlier assay for the altered target site mechanism, USDA researcher Dale Shaner has developed a similar test to detect the relative sensitivity of a weed to glyphosate. .

Until recently, the best scientific option for determining glyphosate resistance was to grow seed in a greenhouse, then spray them with glyphosate and see which ones survive. By the time scientific evidence is in, too many farmers are past the point of no return with resistant pigweed.

The best way to determine glyphosate resistance quickly is common sense. If you know you sprayed a weed with a high enough rate of glyphosate to kill it and it didn't die, it's likely resistant to the herbicide, or tolerant of it in a technical sense.

Shaner's new assay test in non-invasive, can be used on a small leaf sample and generates results in a couple of day.

Though Southeast cotton and soybean farmers may think they have been singled out by Mother Nature and plagued with weeds resistant to herbicides, they are mistaken. Farmers in other parts of the country share their plight — slightly different melody and verse, but same dire consequences.

In southern Illinois, pigweeds are resistant to ALS inhibitors, glyphosate, PPO inhibitors and triazines. Four distinct modes of action and water hemp is resistant to all four in 23 counties in southern Illinois.

"In Missouri we only have 'triple-stacked' weeds, quips University of Missouri Weed Scientist Kevin Bradley. Bradley says the occurrence of resistance to glyphosate, PPO-inhibitor, and ALS-inhibitor herbicides in one weed is still rare throughout the Midwest. However, the implications are dire for farmers, if this level of resistance spreads rapidly through soybean-producing areas of the country, he adds.

The take home message from this latest glyphosate resistance finding by Westra, Shaner and other researchers working at Colorado State University is that the Palmer pigweed/glyphosate resistance story is not going away. Not only is it not going away, it is likely to increase in severity and at a more rapid pace, unless growers take some well thought out actions to manage glyphosate resistant pigweed.

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http://deltafarmpress.com/news/weed-resistance-0112/

Old technology coming out the closet

Jan 12, 2010 10:51 AM, By Elton Robinson, Farm Press Editorial Staff

It's almost like weed control has been transported back to the 1980s, what with all the cold steel, post-directed rigs, hooded sprayers and residual herbicides becoming more prominent in the arsenal.

As glyphosate-resistant weeds continue to march across the Mid-South, many farmers are being forced to pull old weed control technology out of the grass patch.

For some, it's almost like weed control has been transported back to the 1980s, what with all the cold steel, post-directed rigs, hooded sprayers and residual herbicides becoming more prominent in the arsenal.

And weed control costs are rising, too, as well as a critical importance on application timing, both of which came into focus during the weird growing season of 2009, when wet weather prevented so many timely applications.

A resistant pigweed problem got so bad for Gunnison, Miss., producer Kenneth Hood this season that he had to plow under some soybean acres infested with it "after I threw everything I could at them and couldn't control them.

"It's unbelievable how thick they have become since my last disking. If that is any indication of what I've got to fight next year, I hate to think."

Cold steel is not the only old technology pulled out of the closet the last two years, Hood says. "We've hand-weeded and spot-sprayed weeds by hand. We never stopped our post-directed applications. We just went out and tried to control those spots in the field where resistant weeds escaped our traditional applications."

Hood estimates that the additional trips and labor has increased his cost of production by about $30 an acre, "and we've hurt yields and quality as well. Weeds will choke up cotton pickers and combines, and hurt the quality of your crops. Resistance is a broader spectrum problem than we think about."

Weeds in the Mid-South with documented glyphosate resistance include johnsongrass, horseweed, common ragweed, Palmer amaranth (pigweed) and Italian ryegrass.

Cleveland, Miss., rice and soybean producer Nott Wheeler says he is also spending more money on weed control because of resistance. "It's okay as long as soybeans are $10 to $11 a bushel. If the market turns, and I'm confident that someday it will, we will have to weigh the cost of those applications more heavily. At these price levels, we can afford to keep soybeans clean."

Wheeler rotates his rice and soybeans, which is a good way to use different chemistries on resistant weeds. "In soybeans, you get a two-year shot at them, a chance to clean them up."

In rice, resistant pigweed has been an early-season problem for Wheeler. "Once we water up, they pretty much go away. But we've had some infestations that were bad enough where we've had to treat."

Palmer amaranth (pigweed) has always been a prolific breeder and seed producer and grows quickly, but glyphosate resistance has taken the weed to another level for Mid-South farmers.

"It doesn't take much of letting pigweed go before it will take over," Wheeler said. "In our experience, we didn't see it as a big problem because it was coming late in the season, and it wasn't affecting our yield. Then it got to be a problem coming up in the spring and we couldn't do anything with it."

Wheeler has had success using residual products in soybeans to get them cleaned up. "We have put out Valor and Prefix, and that's helped a lot. We've used FlexStar to get better control early on."

Hood first noticed pigweed escapes about four years ago and thought careless applications were to blame. "You'd have five dead plants and one live plant sticking up. It took us a while to understand that we had resistance. I've had to apologize to my farm equipment operators for getting on to them when resistance was the problem, not misapplication."

Timing and knowledge of a resistance problem are two keys to controlling resistant weeds. But in 2009 wet weather wreaked havoc with timing.

"I was fully aware of resistance problems prior to the 2009 season," Hood said. "We hit it with everything we could. The problem was the May rains. We planted the crop, got it up, and even though we thought we had done a good job with post-directed sprays, we couldn't do them in a timely manner. The weeds had gotten too large.

"Pigweeds turned completely brown, but in four days time, they started greening up and took off again. That's what you run into when your timing is off. Timing is the most important factor for controlling resistance. If you hit them when they're small, and you hit them hard enough, you can control them."

In cotton, Hood plans to increase his use of preplant and pre-emergence herbicides, including Prowl and Dual. "It had been 10 years since I've used any kind of yellow herbicide in cotton, but the little bit I put out last year worked perfectly.

"But it needs to be incorporated for pigweeds because they can come from so deep in the soil. There are some other products out there that you don't have to incorporate, but they take some rainfall."

The products will have to hold for a while, noted Hood. "These resistant weeds will start coming up preplant and will keep coming up through August. That's what makes the problem so severe and runs up the cost of production so much."

A late season residual in cotton may also be necessary in cotton, Hood says. "A lot of farmers had gotten away from a layby in cotton because Roundup Flex cotton allowed you to use Roundup all season long. But we're going to have to go back to a residual now, and maybe two.

"We may want to put a layby out in July, early season, and we may have to put another layby out in August."

Both Wheeler and Hood say glyphosate remains a very viable tool in weed control. "It still does a good job," Wheeler said. "We have a few more arrows in the quiver. It doesn't matter whether it's glyphosate or propanil, if you use it enough, something is going to become resistant."

Hood says glyphosate "will still be in our arsenal, but we will not be relying on it as extensively as we have in the past because of the resistance issue."

Current technologies like LibertyLink cotton and soybeans can address the weed resistance issue, but again, timing is a critical issue, noted Hood. "You have to hit the weeds when they're small."

Upcoming technologies such as dicamba-resistant varieties can also help with glyphosate-resistant weeds and grasses, according to Hood. "But I can't wait three years."

In the meantime, Hood says, **"If farmers are going to be forced to apply residuals and change tillage practices, do more spot spraying and post-directed sprays or have to change crop scenarios to change chemistries for better control, then I can't afford to pay for a technology fee. Economics will force me to go to a germplasm or seed variety out there where I don't have to pay for that. Hopefully, those will be available to us."**

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http://deltafarmpress.com/news/baldwin-column-0106/

Resistant weeds — five years out
Jan 7, 2010 8:05 AM, By Ford L. Baldwin, Practical Weed Consultants, LLC.

I recently attended the American Seed Trade Association meeting in Chicago and spoke on the topic of *Putting the Collar on Weeds with New Herbicide Tolerant Traits.*

There are some traits in the pipeline besides Roundup Ready and LibertyLink that I hope will extend our weed control capabilities. The big buzz word now is "stacks." I asked told by more than one industry person at the meeting, "Why are you so hung up on herbicide resistance because in three to five years we will have all of these stacks?"

I am glad they are coming. You know I love new technology. I am trying to feel warm and fuzzy that they are going to solve all of our herbicide resistance problems.

For some reason, however, I am very nervous. Part of the reason for complacency at the grower level, and thus the reason we are using up herbicides one mode of action at the time, is we have always had something newer and better coming.

We have never, however, dealt with potentially losing activity from a herbicide as important as glyphosate.

And, as fast as things are moving, three to five years can be an eternity with resistance development.

Currently I am aware of traits (for soybeans and also other crops) in the pipeline for dicamba tolerance, 2,4-D tolerance, Optimum GAT (glyphosate and ALS inhibitor herbicides), and tolerance to the HPPD inhibitors such as Callisto and Balance. All of these that make it to market will likely be stacked.

A stacked trait a lot of growers would love to have right now is a glyphosate (Roundup and others) plus glufosinate (Ignite) combination. I am frequently told, "I like the LibertyLink potential, but I want to wait until it is stacked with Roundup Ready to use it."

I share the enthusiasm for this combination and to me it makes the most sense of any — at least in the short run. While I do not feel the two herbicides make good tank mix partners, they could sure make a good one-two punch and get some growers past the hurdle of not wanting but one technology on the farm.

Like the other above traits, I am told three to five years is the timeline for getting this stack to the market. If the train wreck is to be averted, I do not believe we have this time to wait.

With the potential stacks from some of the traits mentioned above, everyone seems to believe glyphosate will be the primary herbicide — just as it is now — and the other traits will simply allow us to add an herbicide that will make Roundup Ready back "as good as it used to be."

I sincerely hope that is the case, but I am not as optimistic as some. Well over 90 percent of the soybeans in Arkansas in 2010 will be Roundup Ready. In those fields with major Palmer pigweed infestations, an intensive conventional herbicide program will be required.

If that program works well enough to control the pigweeds, it will control most of the other weeds as well. Therefore, what will glyphosate contribute in those fields? If you miss the pigweeds with the conventional herbicides, glyphosate will control everything but the resistant pigweeds and they are going to choke out the other weeds anyway.

At the rate we are using up the technology, I have no idea what that picture will look like in three to five years, but I have the feeling it will not be pretty.

Next week I will look at the newer traits. I am certainly for getting every possible tool in the toolbox we can. All of the potential new traits can have a place. However, with the exception of LibertyLink, none of the new traits have the potential to be a Roundup Ready by themselves.

We need a rapid increase in crop diversity, herbicide diversity and a ramp up of LibertyLink right now. If we stay on the current path and continue losing the effectiveness of glyphosate, a lot of the new technology we are counting on may not look nearly as good in three to five years as it would if it were available today.

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http://iowafarmertoday.com/articles/2010/01/15/top_stories/glypho1.txt

Glyphosate resistance confirmed in Iowa

By Tim Hoskins, Iowa Farmer Today

Wednesday, January 6, 2010 2:00 PM CST

Uncontrolled weeds grow in a soybean test plot this summer. Within the past year, Mike Owen has confirmed two cases of glyphosate resistant weeds and is investigating another case. IFT photo by Tim Hoskins

Iowa has two confirmed cases of glyphosate-resistant weeds — common waterhemp and giant ragweed.

Mike Owen, Iowa State University Extension weed management specialist, says he is also investigating a possible case of resistant marestail.

"There is no reason why I think it (marestail) would not be glyphosate resistant," he says.

One of the cases of common waterhemp Owen investigated is resistant to glyphosate and ALS group of herbicides.

Iowa's first confirmed case of common waterhemp resistant to the ALS group of herbicides was in 1993, according to the International Survey of Herbicide Resistant Weeds.

Owen says he was able to confirm most fields in Iowa harbor a population of ALS-resistant waterhemp.

One surprise for Owen was the amount of resistance to the PPO class of herbicides. According to the International Survey of Herbicide Resistant Weeds Web site, Iowa also confirmed

common waterhemp being resistant to PPO herbicides in 2009.

While the confirmation of glyphosate-resistant weeds is different, Owen says the message for weed management remains the same — protect yields and not just to kill weeds.

Therefore, he recommends using a soil-applied residual herbicide in the pre-emergence stage.

Aaron Hager, University of Illinois Extension weed management specialist, agrees. In addition, he says all farmers should apply glyphosate early post emerge.

He says early post-emergence application of glyphosate will not kill resistant weeds. Instead, it gives the farmer time to scout for weed escapes and still apply a different class of herbicides that might be more time-dependent.

Hager has been working with a couple populations of glyphosate-resistant weeds. He also confirmed a case of common waterhemp in Illinois that is resistant to four classes of herbicides.

For farmers the most-expensive year for a resistant weed is the first year, when they may not know they have it, Hager notes.

After confirmation, management strategies can be changed to deal with herbicide resistance. For example**, the farmer with four-way-resistant waterhemp might only have the option to turn to LibertyLink crops.**

However, Owen and Kevin Bradley, University of Missouri Extension weed-management specialist, say glyphosate resistance can be managed over time.

Overall, Hager reminds farmers once they have glyphosate resistance they will be dealing with it over many years. Both have dealt with cases where the farmer was able to manage the resistance.

While there are more cases of glyphosate weeds, Hager says it is not anything new. He adds weed scientists have seen a long list of weeds overcoming the new herbicide on the market.

In addition, he says glyphosate will continue to be a tool for farmers to use.

While the International Survey of Herbicide Resistant Weeds lists 16 weeds worldwide that are glyphosate resistant, Hager notes many weeds are not glyphosate resistant.

http://deltafarmpress.com/soybeans/glyphosate-misuse-0104/

Misuse of glyphosate short-sighted risk
Jan 4, 2010 10:03 AM, By Ford L. Baldwin, Practical Weed Consultants, LLC.

An article or so ago I stated that I would get off the glyphosate resistance and Palmer pigweed topics to give you a break. I changed my mind.

The winter period is when growers are planning for next year. If I can just in some small way influence some growers to increase their efforts on resistance management, it will be worthwhile.

I hope it is obvious I have a passion for trying to help preserve our Roundup Ready crop technology. If we continue down the path we are headed, a lot of folks are going to look back in a few years and ask, "why were we so short-sighted?"

For me as a private consultant in a regional popular press article to say I feel glyphosate resistance is a threat to global food production may not get the attention of many people. I am going to attempt to ratchet that up a notch.

A paper by Todd Gaines and other researchers in Australia has just been published online in the U.S. Journal PNAS. The title is "Gene amplification confers glyphosate resistance in Amaranthus palmeri."

In our terms Amaranthus palmeri is Palmer pigweed and this paper documents yet another evolved mechanism of pigweed resistance to glyphosate. The online address for the article is http://www.pnas.org/content/early/2009/12/10/0906649107.

In a recent email, Stephen B. Powles from the University of Western Australia (I consider him the world's foremost authority on herbicide resistance) sent out a personal commentary entitled "Gene Amplification Delivers Resistant Weed Evolution." That commentary will also be published in the PNAS online journal.

I wish to pass along some of the points from Powles' commentary. In plants, glyphosate is toxic because it inhibits a specific enzyme pathway (EPSPS). To date, resistant weeds either exhibit a mutation at the enzyme level or a trait that restricts glyphosate movement to that enzyme.

With gene amplification, the weeds evolve to massively overproduce the EPSPS enzyme due to continued selection pressure from overuse of glyphosate. In Powles' terms, the overproduction of the enzyme acts like a molecular sponge to soak up the herbicide and continue to function normally in the plant.

With that I have told you far more than I know and I am sure you wish to read. The point is the glyphosate resistance snowball continues to pick up speed. Since Arkansas is ground zero for Palmer pigweed, we are right in the middle of it.

In his commentary, Powles said glyphosate resistance evolution is a threat to world food production. He called glyphosate "a one in 100 year discovery that is as important for reliable global food production as penicillin is for battling disease."

In some personal correspondence he said that "twenty years from now this will be in the textbooks as a classical case of a great technology being driven to redundancy by over-use."

I share his passion as a weed science professional to keep trying to get the word out. I keep asking, "Why are we doing this?"

The science in the articles and commentary cited above is beyond my understanding. What I do understand is the train wreck can only be stopped at the grower level. All of the complicated science boils down to whether or not individual farmers are willing to invest in the diversity necessary to reverse the trend.

In some fields it is too late. However, the majority of the situations can either be prevented or salvaged if we just wake up.

The comment I hear constantly now is, "I was considering making some changes in my program, but with this cheap glyphosate I can not afford to." I would submit that you can't afford not to.

Without a serious increase in crop diversity, herbicide diversity and technology diversity on the part of every farmer, before long it won't matter if they give you the glyphosate!

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http://www.thealmonddoctor.com/2009/12/managing-resistant-weed-populations.html

Monday, December 28, 2009

Managing Resistant Weed Populations

Over the next couple of weeks, I will be presenting information regarding weed control in an orchard system. Since herbicide resistant weeds are becoming more prevalent in the San Joaquin Valley (think Hairy Fleabane, Horseweed/marestail), it is becoming more important for growers to utilize practices that reduce the chance of herbicide resistance.

Herbicide resistance is defined as the inherited ability of a plant to survive and reproduce following an exposure to a dose of herbicide that would normally kill the wild type (Think: "We used to get good control of this weed with this herbicide..."). This is different than herbicide tolerance, which is the ability of a species to survive and reproduce a herbicide treatment with no implied selection or genetic manipulation that would make the plant tolerant (Think: "We've never gotten dependable control of this weed with this herbicide...").

Since 1980, cases of herbicide resistant weeds within California has increased from 0 to 21 reported cases. This is mainly due to the change in tillage and herbicide use practices within agriculture. In perennial crops, growers have shifted away from orchard tillage and have become more reliant on herbicide "burn downs" to control weeds in the tree rows. Glyphosate is one of the most widely used herbicides for this practice, and, until recently, has provided good control.

The formation of herbicide resistant weeds is an evolutionary process that occurs due to the application of herbicides. Since most herbicides are reliant upon a single site mode of action, it only takes a minor mutation within the plants genome to become resistant. Furthermore, the high genetic diversity of weed populations provides the opportunity for weeds to contain a mutation, thus yielding an "escape." Once the weed is unable to be controlled by the herbicide, it produces progeny that is also resistant. These seeds tend to move outward from the point of origin, causing a "hotspot" pattern within the orchard.

To control these hotspots, growers need to rotate to different herbicide modes of action. The mode of action of an herbicide is the way it alters or inhibits specific physiological or biochemical processes. This is not to be confused with active ingredient or trade name. This can be found on some herbicide labels as the WSSA or HRAC group number found below the herbicides active ingredient. Growers should also avoid the year-after-year use of the same herbicide/mode of action. In some cases, a tank mix of two products that target the escaped weed must be used.

Growers should also apply herbicides using the proper rate and at the proper timing. Herbicides give the greatest control when the weed is no larger than a silver dollar (1.5 inch diameter). As the weed grows larger than this, it becomes harder and harder to control. Growers also need to reduce the spread of weed seeds throughout their orchards. Spread may occur from harvesting equipment, spray rigs, and also natural conditions such as wind. Keeping notes of the herbicides used and escapes observed is also advised.

If you feel that you may have a resistant weed population, it is best to use any means necessary to control the weed. This may include hand weeding, herbicide tank mixes, and/or tillage. Controlling a small patch of resistant weeds is much easier than an entire orchard. It may also be of interest to contact you local farm advisor to report the incident, but the weed MUST be controlled before it goes to seed.

http://deltafarmpress.com/soybeans/herbicide-programs-1210/

Using up herbicide programs

Dec 10, 2009 10:19 AM, By Ford L. Baldwin, Practical Weed Consultants, LLC.

A couple of regular readers say they have enjoyed the pigweed articles I've written, but have enjoyed about all of them they could stand for a while! I only have a couple more and I will move on to something else.

It is interesting that someone can find a soybean rust symptom — or just something that looks like one — and everyone goes into a panic. However, we continue to drive the Roundup Ready technology off the cliff one year at the time and few seem to notice.

That is not to say soybean rust is not a very serious issue, but weeds will ultimately dictate your production system.

To stop using up modes of action one at the time is going to take a change in the herbicide industry's "sell what you can now" mentality, a change in the way re-sellers think, and a change in grower use patterns. Unfortunately, I do not see any of those changing anytime soon, but I have the most faith in changing grower use patterns.

The weeds will ultimately dictate what the weed control program will be. However, until we become more proactive managing resistance, we will continue to use up technology one mode of action at the time.

I hear a lot of comments (some from weed science counterparts) along the lines of "even though we have some resistance problems, Roundup Ready will continue to be the centerpiece in our weed control programs." Is it really if we continue down the same path we are headed?

Palmer pigweed is out of the bottle and that one is going to be hard enough to cork back up.

Marestail continues to be hard to manage in a lot of areas, especially if you want to stay in a conservation tillage system.

Ryegrass resistance has become a huge problem in some areas of Arkansas and Mississippi and that one is going to get worse.

Common ragweed, giant ragweed and johnsongrass resistance have been documented in Arkansas.

Waterhemp resistance has been documented is states where they have it instead of Palmer pigweed.

Next to Palmer pigweed, the weed that concerns me most is barnyardgrass. To my knowledge glyphosate resistance has not yet been documented, but a lot of folks are having a more difficult time controlling it. As genetically diverse as the barnyardgrass family is, I would be surprised if that is not the next weed documented.

Without being critical of anyone, it sometimes seems as if the weed science community is the only one overly concerned about what is slowly happening here.

As we continue to increase the populations of the resistant species we already have and as we continue to develop new ones, how much longer will Roundup Ready be a useful tool? If we get to that, then we have lost the best weed control technology any of us could ever have imagined.

In some ways we are boxed in for the short run as most of the soybean varieties are Roundup Ready. This is a tribute to the success of the technology. However it also means it will be difficult to make wholesale changes on a lot of acres.

We are rapidly heading for a Roundup Ready program based upon conventional herbicides. Conventional herbicide programs were not working well before Roundup Ready, so how can they be the answer now?

In addition, we will continue putting tremendous selection pressure on the system with "cheap glyphosate."

The way to stop the train wreck from being any worse is to rotate to crops such as corn that are not as dependent on glyphosate and to rotate herbicide modes of action. I am high on the LibertyLink technology because it offers a brand new mode of action with most of the same attributes of a Roundup Ready program.

I am constantly told, "I think I can get one or two more years from my Roundup Ready program. When you get there, then you must begin to use up the next mode of action. The weeds will ultimately dictate the program. You can be much more proactive by dictating the program to the weeds and keep Roundup Ready a valuable technology on your farm for years to come.

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http://www.prweb.com/releases/2009/11/prweb3222654.htm

Glyphosate-Resistant Weeds: Can We Close the Barn Door?

In a recent presentation to the U.S. Environmental Protection Agency, officials from the Weed Science Society of America reported that nine weed species are now resistant to glyphosate, the nation's most widely used herbicide. Researchers say cost-competitive management techniques can keep resistance from spreading, while also improving crop yields.

"Unfortunately it is too late to prevent glyphosate resistance from developing," says David Shaw, WSSA president. "It's a problem that is already with us."

Lawrence, Kansas (PRWEB) November 18, 2009 -- Glyphosate is the most widely used herbicide in the nation and a mainstay of weed control for both farmers and homeowners. Over the last 13 years, it has been applied to more than a billion acres. But there is a downside to the product's popularity. Scientists are increasingly concerned about the growing number of weeds developing resistance to glyphosate.

In a recent presentation to the U.S. Environmental Protection Agency, officials from the Weed Science Society of America (WSSA) reported that nine weed species in the United States now have confirmed resistance to glyphosate. Among these weeds are strains of common ragweed (Ambrosia artemisiifolia), common waterhemp (Amaranthus rudis), giant ragweed (Ambrosia trifida), hairy fleabane (Conyza bonariensis), horseweed (Conyza canadensis), Italian ryegrass (Lolium multiflorum), johnsongrass (Sorghum halepense), Palmer amaranth (Amaranthus palmeri) and rigid ryegrass (Lolium rigidum).

"Unfortunately it is too late to prevent glyphosate resistance from developing," says David Shaw, WSSA president. "It's a problem that is already with us. The challenge now is to adopt effective management techniques that can keep resistance from spreading."

The consequences of resistance are particularly troublesome for farmers who grow soybean, corn, cotton and sugar beet crops genetically engineered to tolerate glyphosate. Many of these farmers rely almost exclusively on glyphosate for weed control throughout the growing season. Using a single herbicide, though, increases the odds that the weed population will shift to resistant plants that are able to escape treatment and compete with crops for moisture and nutrients.

University scientists recommend a number of techniques for preventing or managing resistance. One of the most common recommendations is to rotate the types of herbicides used for weed control – making it tougher for weeds to adapt. Shaw says that initially many farmers were slow to recognize the seriousness of glyphosate resistance and to adopt this best management practice. However, educational programs in the last few years have greatly increased grower awareness and management efforts.

"One issue may have been the mistaken perception that adopting resistance management practices will cost more, since glyphosate tends to be very affordable," Shaw says. "But studies show just the opposite is true."

In a four-year research project now underway in six key agricultural states (Illinois, Indiana, Iowa, Mississippi, Nebraska and North Carolina), researchers are comparing the economics of university-recommended, herbicide resistance management programs with the use of glyphosate as an exclusive treatment for weed control. As of the end of the third year of the study, researchers say the net returns on fields managed according to recommended best practices are equal to or greater than the returns on those where glyphosate is used alone. Increased yields appear to offset any increase in herbicide costs.

"When glyphosate was first introduced for weed control, its unique way of inhibiting protein synthesis and growth in plants led many to believe that resistance would not be an issue," Shaw says. "Obviously that prediction was wrong. However, best management practices can slow the development of resistant weeds, and one effective approach is to rotate glyphosate with herbicides that work very differently."

Tips for Backyard Gardeners to Prevent the Development of Herbicide Resistance

Most backyard gardeners will recognize glyphosate as Roundup® – one of the many brand names for the popular herbicide. To delay the onset of resistance and maintain weed-free natural areas, flowerbeds and gardens, WSSA says homeowners should follow the same approach university researchers recommend for farmers. They should adopt a broad set of weed management tools and not rely on Roundup alone.

"By rotating the types of herbicides used and by complementing them with hoeing, hand-pulling, black plastic and other nonchemical weed control measures, we can prevent or delay resistance and preserve glyphosate as an effective weed control tool," Shaw says.

About the Weed Science Society of America

The Weed Science Society of America, a nonprofit professional society, was founded in 1956 to encourage and promote the development of knowledge concerning weeds and their impact on the environment. The Weed Science Society of America promotes research, education and extension outreach activities related to weeds, provides science-based information to the public and policy makers, fosters awareness of weeds and their impact on managed and natural ecosystems, and promotes cooperation among weed science organizations across the nation and around the world. For more information, visit www.wssa.net.

http://paraquat.com/news-and-features/archives/us-growers-must-fight-glyphosate-resistance

US growers must fight glyphosate resistance

Tuesday, 08 June 2010

Glyphosate tolerant crops need more than just glyphosate for weed control

Farmers in the US have been aware for some time of the threat glyphosate resistant weeds pose to their crops and livelihoods. Now, the public is becoming more aware too after recent media attention following the publication of the US National Research Council's report: *Impact of Genetically Engineered Crops on Farm Sustainability in the United States*1. The report confirmed the substantial economic and environmental benefits of GM crops, but warned that care was needed to preserve the value of the technology, especially with the threat posed by glyphosate resistant weeds. Farmers growing herbicide resistant crops must ensure that a diverse range of agronomic practices are used to control weeds and must not simply rely on one herbicide mode of action.

Unfortunately, for many growers the simplicity of glyphosate-based weed control is hard to resist – if they are yet to experience any problems. However, they should heed the warnings of both weed resistance experts and fellow farmers. Australian Professor Steve Powles, one of the global leaders in weed science, has warned that "... glyphosate will be driven to redundancy in large parts of North America and South America, unless growers diversify weed control now."2

Palmer pigweed (*Amaranthus palmerii*) is a huge problem in southern US states. Prominent weed scientist Ford Baldwin has stated that to help prevent resistance, a burndown program using paraquat should be used instead of glyphosate3. Some farmers call the early stages of a Palmer pigweed infestation *"the red tide"* because the reddish colored seedlings emerge so fast between the crop rows4. Early weed removal is critical if crop yields are not to be affected. Weed species that have become resistant to glyphosate are some of the most aggressive yield-reducers. Surprisingly low densities of weed infestation can have devastating effects on crop yields if left unchecked.

Effect of glyphosate resistant weeds on crop yields*

Weed	Crop	Yield reduction
Amaranthus palmerii	Soybean	2 weeds/20 row feet can reduce yield by at least 23%
Amaranthus palmerii	Corn	1 plant/m2 can reduce yield by 33%
Amaranthus palmerii	Cotton	8 plants/m2 can reduce yield by up to 91%
Ambrosia trifida	Soybean	1 plant/m2 can reduce yield by 52%
Ambrosia trifida	Corn	2 plants/m2 can reduce yield by 37%

* *www.resistancefighter.com*

In the US, 10 weed species now have populations officially recorded as being resistant to glyphosate over thousands of acres in many states5.

US populations of confirmed and suspected glyphosate resistant weeds on www.resistancefighter.com

The full impact of this statistic comes home when outbreaks are plotted on an interactive map which can be found at www.resistancefighter.com. The map pinpoints where glyphosate-resistant weeds have been identified or suspected down to the county level. A Solutions Builder module on the website allows users to develop customized weed management programs for their own farm. The site also includes weed management news and a frequently updated Ask the Expert blog featuring advice and recommendations from Chuck Foresman, Syngenta manager of weed resistance management strategies.

Especially worrying are the increasing number of cases of weed populations resistant to both glyphosate and herbicides with other modes of action. In Illinois, a population of waterhemp (*Amaranthus tuberculatus)* is known to be resistant to four modes of action of common herbicides: glyphosate, triazines (*eg* atrazine), ALS inhibitors (*eg* imazethapyr or Pursuit) and PPO inhibitors (*eg* lactofen or Cobra) 2.

Using herbicides with different modes of action is imperative to preserve the enormous benefits of using glyphosate in weed management systems. Paraquat can be used as an alternative, much faster acting and rainfast, burndown herbicide to ensure crops get off to a clean, weed-free start. Paraquat can also be applied through hooded sprayers in between crop rows. Unlike systemic glyphosate when applied to conventional non-GM crops, paraquat's contact-only action does not risk causing crop damage. Small amounts of spray landing on crop leaves cause only local damage and paraquat is inactivated immediately on reaching the soil.

Integrated weed management systems which rotate herbicide modes of action and are custom-built for specific crop situations will fight glyphosate resistance.

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2. Agriculture Online

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Notes

The brand name for the leading paraquat product is *Gramoxone*.

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By Jack Kaskey

May 5 (Bloomberg) -- Dow Chemical Co. plans to add a gene to its corn, cotton and soybean seeds that will allow growers to use a second herbicide to control weeds not killed by Monsanto Co.'s Roundup product.

DHT, or Dow Herbicide Tolerance, will be combined with Roundup tolerance, allowing growers to kill problem weeds with Dow's 2,4-D herbicide, Antonio Galindez, president of Dow AgroSciences, said today in a webcast of a UBS AG conference presentation. DHT may be available by

2012 in SmartStax corn, by 2013 in soybeans and by 2015 in cotton, he said.

"DHT will bring an unsurpassed solution for weeds that are hard to control," Galindez said. "We want to see our DHT trait in as many acres as possible."

DHT is worth two to three times more than Smartstax corn seed, developed with Monsanto, which has a net present value of $500 million, Dow Chief Executive Officer Andrew Liveris said in October. A half-dozen weeds, such as pigweed and water hemp, have developed resistance to Roundup, the world's top selling herbicide, Monsanto Chief Financial Officer Carl Casale said at the UBS conference.

Monsanto, the world's biggest seed producer, is developing dicamba-resistant seeds for 2013 to help farmers control problem weeds with a second herbicide, Casale said.

Dow, based in Midland, Michigan, fell 90 cents, or 3.1 percent, to $28.41 at 4 p.m. in New York Stock Exchange composite trading. St. Louis-based Monsanto fell 49 cents to $60.98.

--Editors: James Langford, Steven Frank

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EPA's Response to Resistance Management and Herbicide-Tolerant Crop Issues
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Accessed: 28/07/2010 10:23

EPA's Response to Resistance Management[1] and Herbicide-Tolerant Crop Issues

DIANA M. HORNE[2]

Abstract. The regulation of transgenic plants is at the very early stages of dialog between the U.S. Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), and the U.S. Department of Agriculture (USDA). Herbicide resistance is discussed in the broader terms of resistance management and of the cooperative efforts underway involving governments, industry, academia, and the environmental community on an international level. A new body, the International Organization for Resistant Pest Management (IOPRM) was formed to implement pesticide resistance management programs worldwide. The research base for integrated pest management programs which form the context for pesticide resistance management programs is in need of expansion. Public and private efforts to expand this base converge in an ambitious collaborative program between the U.S. EPA and USDA entitled the National Integrated Pest Management Forum. Finally, the potential role of EPA in the regulation of resistance management is discussed.
Additional index words: Biotechnology, herbicide resistance, integrated pest management, selective herbicide.

INTRODUCTION

The area of regulation of transgenic plants is in its infancy. The U.S. Environmental Protection Agency (EPA)[3], the Food and Drug Administration (FDA)[3], and the Department of Agriculture (USDA)[3] are currently engaged in extensive discussions regarding the relative roles of the respective federal agencies in this area.

A clear distinction must be made between EPA's authority to regulate pesticidal and non-pesticidal transgenic plants. The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)[3] defines a pesticide as . . ."any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest, and any substance or mixture of substances intended for use as a plant regulator, defoliant or desiccant. . .". Under this definition, it is likely that the pesticidal component of transgenic plants falls under the regulatory authority of FIFRA. EPA also sets tolerances for pesticides under the Federal Food, Drug and Cosmetic Act (FFDCA)[3] and, to the extent that residues are involved in edible portions of food or feed, EPA will retain that role regarding transgenic plants. Any nutritional changes will probably be regulated by the FDA and the USDA, Animal and Plant Health Inspection Service (USDA/APHIS)[3] will probably retain its role in the introduction of new plant varieties.

Since 1986, EPA's Office of Pesticide Programs, in a cooperative review process with USDA/APHIS, has reviewed approximately 50 small-scale field test proposals for pesticidal transgenic plants. Given that commercially viable plants are now ready to be tested on a large scale, the Agency recognizes that there is an imminent need for the regulation of large-scale testing and commercial release of pesticidal transgenic plants.

EPA's role in the regulation of herbicide-tolerant crop (HTC)[3] varieties is more oblique. EPA has no direct authority over the plant, as herbicide tolerance does not include production of pesticidal compounds. But, EPA will regulate new herbicide uses.

EPA's interest in HTC stems from a broader interest in pest resistance management, and more specifically in the weed resistance issues surrounding the potential widespread use of HTC varieties. EPA's Office of Pesticides and Toxic Substances also has a strong interest in promoting the development and broader use of integrated pest management (IPM)[3] technologies which make use of culturally and biologically-intensive options, in addition to synthetic chemicals, within environmentally and economically sustainable crop production systems.

[1]Received for publication July 3, 1991 and in revised form Mar. 30, 1992.

[2]Special Asst. for Integrated Pest Management, U.S. Environmental Protection Agency, Office of Pesticide Programs, Washington, DC 20460.

[3]Abbreviations: EPA, Environmental Protection Agency; FDA, Food and Drug Administration; USDA, U.S. Department of Agriculture; FIFRA, Federal Insecticide, Fungicide and Rodenticide Act; FFDCA, Federal Food, Drug an Cosmetic Act; USDA/APHIS, U.S. Department of Agriculture/Animal and Plant Health Inspection Service; HTC, herbicide-tolerant crop; IPM, integrated pest management; IOPRM, The International Organization for Resistant Pest Management; NASA, National Aeronautics and Space Administration; FAO, Food and Agriculture Organization; WHO, World Health Organization; OMB, Office of Management and Budget.

THE INTERNATIONAL ORGANIZATION FOR RESISTANT PEST MANAGEMENT (IOPRM)[3]

Over the past decade, problems of pest resistance have surfaced as a major issue in agriculture, as well as public health. A number of formal and informal groups have been working independently to resolve these problems. But the global scale of the problem and the scarcity of resources require a greater degree of direction and coordination. IOPRM, which has been in the planning stages for approximately two years, hopes to serve as the umbrella organization with which all other groups concerned with pest resistance and its management can affiliate. The goals of the organization are to provide an international forum to: a) promote the philosophy of pest resistance management within the context of IPM systems, and b) facilitate implementation programs in industrial and developing nations and the emerging democracies.

IOPRM is an international organization which: a) is focused on implementing pest resistance management/ IPM programs globally; b) represents the multi-sectoral forces of industry, government, academia, environmental community, and grower groups; c) is committed to long-term (5 to 10 yr) followup of in-country programs; d) provides the forum for multi-lateral agricultural development programs among several donor nations; e) fosters global networking among specialists in developing and industrialized countries; f) fosters close cooperation with the Food and Agricultural Organization (FAO)[3] and other intergovernmental groups; and g) promotes broad-scale education/training that includes the farmer as a key participant in the pest management decision-making process.

It is largely recognized that the development of pest resistance is accelerated by excessive dependence upon single control tactics, whereas integrated control programs using biological, chemical, cultural, as well as genetic tactics delay resistance. Resistance management and IPM are virtually synonymous in that an integrated program will also be an effective pest resistance management program.

In addition, successful resistance management programs will address other health and environmental problems; e.g., groundwater contamination, food safety, effects on endangered species, and worker safety, by virtue of the fact that such programs generally incorporate biological and cultural options in addition to chemical approaches.

The approach IOPRM is taking in its operations is to: a) develop training programs designed to implement pest resistance management programs within the context of IPM programs for developing nations and emerging democracies; b) promote a high degree of in-country coordination among farmers, research, extension, and technical support personnel, as well as with national policy makers; c) provide long-term commitment to follow up and tracking of implementation efforts to assure sustainability of the programs; d) leverage limited resources by close cooperation with FAO, World Health Organization (WHO)[3], and other international organizations, building on the programs already being executed by these organizations, and using the progress already made in developing in-country infrastructures for regulatory and information transfer. IOPRM's approach will be to fine tune training efforts to focus more specifically on managing pest resistance within the broader context of IPM systems; and e) foster global networking and data base development among researchers, extension, and plant protection specialists in both industrialized and developing nations.

STRUCTURE OF IOPRM

IOPRM is comprised of six working groups representing over one hundred world experts in pest resistance:

a) Insect Resistance Management Working Group, composed of four task groups.

i) The Cotton Task Group, focusing initially on *Heliothis* resistance management in Indian cotton (*Gossypium hirsutum* L.). Cooperative efforts are currently underway with USDA's Office of International Cooperation and Development, the industry sponsored Pyrethroid Efficacy Group, the Indian Ministry of Agriculture, Indian Council on Agriculture Research, Indian state governments, donor agencies, and philanthropic organizations to address this issue;

ii) the Tree Fruit Task Group, considering implementation projects for *Tetranychid* mite and disease resistance management on apples [*Malus sylvestris* L. (Mill.)] in Mexico and Poland, and on citrus in Brazil;

iii) the Vegetable Task Group, addressing Diamond Back Moth (*Plutella xylostella*) management in Mexico, Central and South America, and Southeast Asia;

iv) the Public Health Vector Task Group, developing an implementation program for malaria mosquito resistance management in the Caribbean Basin.

b) Weed Resistance Management Working Group.

c) Pathogen Resistance Management Working Group.

d) Charter Working Group. This Working Group is developing an overall Charter for the organization.

e) Implementation Constraints Working Group. This Working Group will be addressing the regulatory, socio-political, economic, and other constraints to implementing pest resistance management programs. This Group will act in concert with the three Technical Working Groups to address and resolve potential constraints prior to implementation.

f) Communications Working Group. This Working Group will address the development of a global resistance management/IPM data base linking industrial and developing nations. This network will be a critical element in the long term follow up of implementation programs by allowing research and extension personnel in the host nation direct contact with their participating counterparts in other parts of the world.

FIRST INTERNATIONAL PEST RESISTANCE MANAGEMENT CONFERENCE

Recommendations and specific protocols will be presented by the IOPRM Working Groups at the First International Pest Resistance Management Congress, scheduled for November, 1992 in Washington, D.C. Participation in the Congress will include invited decision-makers representing all sectors involved, including the governments of those countries hosting pilot programs and of contiguous nations, as well, in the interest of developing regional projects. The European nations have already expressed a keen interest in hosting a second International Congress in two to four years to review the progress made in the pilot programs and to discuss additional implementation programs.

THE NATIONAL INTEGRATED PEST MANAGEMENT FORUM

On a national level, EPA, and USDA have jointly initiated a new effort aimed at integrating and focusing the IPM research planning process across agencies and across disciplinary lines. Participants in the Forum include all appropriate USDA agencies and several EPA offices; state research and extension agencies; users; environmental/consumer groups; philanthropic organizations; agrichemical, biotechnology, biological control and seed industries; and food processors and marketers. This ambitious project is entitled the National Integrated Pest Management Forum. It springs from a Congressional directive contained in 1990 Appropriations Report language for both USDA and EPA. That directive was to establish an advisory body to plan and direct the research, development, and transfer of biologically-based IPM systems. The response on the part of USDA and EPA was to develop plans for two public/private forums; one addressing biologically-intensive agricultural production systems and the other addressing urban site management systems. The whole effort is modeled after the National Aeronautics and Space Administration's (NASA)[3] moon program. This highly successful program generated broad acceptance of that goal as a national priority and involved assembling the best experts to cooperate in an interdisciplinary approach to achieve a highly focused set of goals with challenging time frames.

One of the primary goals of the Forum is to achieve vertical integration through the agencies of USDA, offices of EPA, and state programs. The lack of this type of integration has been viewed by Congress, the Office of Management and Budget, and others as a primary constraint to implementing holistic production systems. By aligning all the programs that have a role to play: biological control, sustainable agriculture, IPM, food safety, water quality, and EPA's pollution prevention programs, we hope to leverage resources to advance IPM, which is really at the heart of these various programs and policy thrusts. There is a tremendous amount of synergy and leveraging of energies that can be accomplished by bringing players to the table who have not traditionally interacted before in research planning. In this regard, the Forum is also intended to serve as an operational paradigm for commodity and trade organizations to gain access to the federal and state research infrastructure to meet their particular needs, using private resources. Participation in the Forum is very broad and includes EPA, USDA, and state agencies; the environmental, academic and user community, and industry.

To achieve the broad goal of environmentally sustainable agricultural production systems, it will be necessary to change the research planning process from one that is discipline, program, and agency-oriented, to one that integrates research across all pest classes at the commodity level and one that involves close cooperation among all the appropriate federal and state agencies.

Increasingly, research programs will need to be long-term, highly focused, highly leveraged, and targeted at nationally agreed-upon goals. The current planning process does not provide the critical mass of funds to do this. The public sector, alone, cannot provide this critical mass. There is an ever-increasing need for the private sector to join in the dialogue and pool resources to achieve the broad changes in production and product delivery systems that will be needed to accommodate the new generation of biologically-based options.

There is also an unprecedented need for industry to cooperate to develop and deliver the products necessary to support these new production systems. Introduction of single control tactics without an integrated production system, involving complementary control measures, will lead to the development of pest resistance to the new biological products as surely as it has with conventional chemicals. Such cooperation has precedent and is possible by the *Technology Transfer Act* which has been used successfully in other innovative programs.

STRUCTURE OF THE FORUM

The Agricultural Forum is planned for June 1992. Five Action Teams have been constituted for corn/soybean, cotton, tree fruits, vegetables, and a cross-cutting team, addressing regulatory and policy constraints to broader implementation of IPM strategies.

Corn/soybean and cotton were chosen because of their status as the nation's largest pesticide users; tree fruit and vegetables because of food safety concerns raised in the National Academy of Science's Delaney Report.[4] These Action Teams are multi-disciplinary, multi-sectoral and multi-regional and their charge is to: a)Define a research plan and technology transfer strategy to align current production systems with the next generation of biologically-based options, moving that system into the 21st century; b) identify and devise strategies to circumvent policy, regulatory, and other constraints to implementing IPM systems for that commodity; c) seek out opportunities for public/private partnerships for implementing the various phases of the plan; and d) implement the Forum recommendations which are accepted as national priorities.

These plans and the cross-cutting issues will be presented to the broader audience of decision makers representing the various sectors at the Forum. The recommendations will be published and presented up through the administrative hierarchies, to the Office of Management and Budget (OMB)[3], and to Congress.

In an effort to lead the way toward greater leveraging of public research dollars for IPM and sustainable agriculture, EPA's Office of Pollution Prevention is negotiating a Memorandum of Understanding with USDA's Cooperative State Research Service's Sustainable Agriculture Research and Education Program. Each agency will contribute funds to establish the first jointly administered State Competitive Grants Program for agricultural research. We look to this joint agreement as the centerpiece for broader cooperation between EPA and the agencies of USDA.

REGULATORY PEST RESISTANCE MANAGEMENT A ROLE FOR EPA?

A key issue inevitably surfaces in discussions such as these. Is there a role for EPA to play in promoting the development and implementation of pest resistance management technologies? EPA currently administers the Section 18 Emergency Exemption Program mandated by FIFRA. This program is a means for the Agency to authorize use of a pesticide for a non-registered emergency use. Over the past four years, the Office of Pesticide Programs has received a dramatically increasing number of Section 18 requests based on the lack of an efficacious registered compound, due to the development of pest resistance.

In recent years, resistance or cross-resistance has evolved to three of the major groups of herbicides for which HTCs are being considered, e.g., the triazines, sulfonylureas, and imidazolinones. It is reasonable to assume that widespread use of HTCs and associated herbicides will exert significant pressure on additional populations of weeds to develop resistance to these classes of herbicides.

Can, and should, EPA play an expanded role in pest resistance management? Would it be appropriate, for example, for the Agency to require that transgenic plants (both of the pesticidal, as well as the herbicide-tolerant varieties) be used only within the context of a resistance management program? That is, an IPM program that incorporates cultural, biological, and chemi-

[4]Regulating Pesticides in Food: The Delaney Paradox, Washington, DC, National Academy Press, 1987.

cal tactics within a production system that minimizes reliance on any single control tactic.

The benefits of such an approach would be two-fold: It would focus research on biologically and culturally-based options to complement existing and emerging synthetic chemical control tactics, and 2) it would promote a maintainable diversity of effective control options (both chemical and biological), by requiring the use of systems which manage the development of pest resistance, thereby extending the useful life of each component tactic.

Above all, we must avoid promoting strategies that make short term economic sense at the expense of those that are environmentally and economically sustainable in the long term. In the case of HTCs, we must ask what long term effects this new technology will have on herbicide use patterns, productivity, yield, and farmer profitability, as well as on water quality and food safety.

Lastly, I would challenge the pioneers in the agrichemical and biotechnology industry to look beyond the obvious approaches that may lead to short term increases in market share to more creative sustainable approaches that answer the needs of the farmer, as well as those of the consumer and future generations. The companies that see the creative potential in this perspective will emerge as leaders in these ground-breaking areas.

FR Notice Sept. 27, 2002 (~~starts~~ AR 3164)
Applies to conv'l alfalfa

Comment: In many parts of this FR Notice, it is not possible to tell who has written it, EPA or Monsanto. As a member of an organization working hard to promote an environmentally sound, economically viable, socially just and humane agriculture and food system in this country, I was expecting to see evidence of an agency working to protect human health and our environment, this is very disappointing. Furthermore, there is no consideration given here to the effects the increased use of this pesticide may have on the soil. Lab studies have demonstrated that glyphosate reduces nitrogen fixation associated with legumes and increases the susceptibility of crop plants to a number of diseases. Roundup is toxic to mycorrhizal fungi, with effects on some species observed at concentrations of 1 ppm, lower than those found in soil following typical applications.

Agency response. Publication of petitioner-generated summaries is dictated by the FFDCA, *21 U.S.C. 346a*(d)(3). The Notice clearly indicates that the petitioner, Monsanto, has written the summary. However, much of this information can be found in the Agency's risk assessment document/supporting documentation for glyphosate. EPA has conducted a complete and thorough review of the available data for glyphosate. Based on the risk assessments conducted for glyphosate, the Agency determined that there is reasonable certainty that [*60939] exposure to glyphosate will not pose unreasonable risks or adverse effects to humans or the environment.

The Agency has received no reports indicating that the use of glyphosate adversely effects nitrogen fixation in legumes or that it increases the disease susceptibility of crops. These type of environmental considerations are more appropriately raised in connection with the FIFRA registration process.

H. Biotechnology Related Issues

Comment: Several comments were received in the public docket that expressed concern over the tolerance approvals for glyphosate that will directly support new uses in glyphosate-tolerant crops, namely wheat, rice and bentgrass. The list of commenters are as follows: Mark Trechock/Staff Director/Dakota Resource Council, Annie Ray/Oregon Rural Action, Helge Hellberg/Marketing Director/California Certified Organic Farmers, Lauran Dundee/Regional Outreach Coordinator/Partners for Global Justice and Sustainable Communities, Kevin L. Williams/Field Coordinator/Western Organization of Resource Councils, Suzin Kratina/Chair of the Food Safety Task Force/Northern Plains Resource Council, Harriet Ritter and Renata Brillinger.

Agency response. The rice grain tolerance of 15.0 ppm initially requested by Monsanto Company and cited in the Notice of Filing Pesticide Petition to establish a Tolerance for Glyphosate in or on Food (April 17, 2002, *67 FR 18894)*, is not included in this final rule.

Tolerance actions for glyphosate are considered independently of the other regulatory assessments that a new crop trait must pass before it can be commercialized. Three U.S. Federal agencies regulate crops incorporating traits derived from biotechnology. The Food and Drug Administration (FDA) has responsibility for evaluating the safety of crops derived through biotechnology for use as food and feed. The U.S. Department of Agriculture, Animal Plant Health Inspection Service (USDA APHIS) is responsible for agronomic characteristics and environmental impact. EPA is responsible for the assessment of the human health and environmental risk of pesticide products, including plant-incorporated pesticides, and their registration under FIFRA, as amended. Commercialization by Monsanto of additional glyphosate-tolerant crops, i.e., wheat, rice and bentgrass, cannot occur until such time as the USDA APHIS and the FDA have received and evaluated necessary data from the registrant and granted necessary approvals. As of 2002, Monsanto has submitted a petition to USDA APHIS for GM bentgrass.

Despite the separate nature of the evaluations and approvals, much closer communication has developed between the three agencies in recent years. In early 2001, EPA and USDA APHIS established an interagency work group for products derived from biotechnology. Through this joint working group, EPA consults on a stewardship plan for each new herbicide-tolerant crop that addresses the management of pest resistance and the potential for weedy volunteer crops in their herbicide-tolerant crops and in crop rotations. This stewardship plan is then incorporated into a full environmental impact assessment by USDA APHIS that addresses the potential for development of resistant weed populations through pollen flow, in addition to effects on non- target organisms and agricultural practices. EPA and USDA APHIS have established a strong working relationship through this joint review process that helps ensure that the concerns of both agencies are adequately addressed prior to final approval by either.

AR3164 - Glen Rogan emails this to Virgil

AR3158 - Glen to Virgil on 2/16/05 glyph tol. on alfalfa seed of 0.5 ppm

AR3172

AR3159 - FR notice - tolerance
2/17

Based on the incomplete status of the interagency approval process discussed above, EPA has decided not to register the use of glyphosate in or on herbicide-tolerant wheat or herbicide-tolerant bentgrass at this time.

Some commenters express concern over the potential contamination of organic crops through pollen drift from herbicide-tolerance crop varieties that may be grown on near-by farms. The issue of organic operations in proximity to operations that employ methods that are prohibited under organic rules is discussed in the National Organic Program, Final Rule, available on the USDA Web site at: http://www.ams.usda.gov/nop/nop2000/Final%20Rule/nopfinal.pdf.

IV. Statutory Findings

The petition requested that 40 CFR 180.364 be amended by establishing a tolerance for residues of the herbicide glyphosate, in or on animal feed, nongrass, group at 400 part per million (ppm), grass, forage, fodder and hay, group at 300 ppm, wheat, forage at 10 ppm, wheat, hay at 10 ppm, and adding the potassium salt of glyphosate to the tolerance expression.

Section 408(b)(2)(A)(i) of the FFDCA allows EPA to establish a tolerance (the legal limit for a pesticide chemical residue in or on a food) only if EPA determines that the tolerance is "safe." Section 408(b)(2)(A)(ii) defines "safe" to mean that "there is a reasonable certainty that no harm will result from aggregate exposure to the pesticide chemical residue, including all anticipated dietary exposures and all other exposures for which there is reliable information." This includes exposure through drinking water and in residential settings, but does not include occupational exposure. Section 408(b)(2)(C) requires EPA to give special consideration to exposure of infants and children to the pesticide chemical residue in establishing a tolerance and to "ensure that there is a reasonable certainty that no harm will result to infants and children from aggregate exposure to the pesticide chemical residue...."

EPA performs a number of analyses to determine the risks from aggregate exposure to pesticide residues. For further discussion of the regulatory requirements of section 408 and a complete description of the risk assessment process, see the final rule on Bifenthrin Pesticide Tolerances *(62 FR 62961,* November 26, 1997) (FRL-5754-7).

V. Aggregate Risk Assessment and Determination of Safety

Consistent with section 408(b)(2)(D), EPA has reviewed the available scientific data and other relevant information in support of this action. EPA has sufficient data to assess the hazards of and to make a determination on aggregate exposure, consistent with section 408(b)(2), for a tolerance for residues of glyphosate on animal feed, nongrass, group at 400 ppm, grass, forage, fodder and hay, group at 300 ppm, wheat, forage at 10 ppm, and wheat, hay at 10 ppm. EPA's assessment of exposures and risks associated with establishing the tolerance follows.

A. Toxicological Profile

EPA has evaluated the available toxicity data and considered its validity, completeness, and reliability as well as the relationship of the results of the studies to human risk. EPA has also considered available information concerning the variability of the sensitivities of major identifiable subgroups of consumers, including infants and children. The nature of the acute toxic effects caused by glyphosate are discussed in the following Table 1 as well as the no observed adverse effect level (NOAEL) and the lowest observed adverse effect level (LOAEL) from the toxicity studies reviewed in the following Table 2. [*60940]

Table 1.--Acute Toxicity of Glyphosate Technical

Guideline No.	Study Type	Results
870.1100	Acute oral	LD[50] > 5,000 mg/kg Toxicity Category IV
870.1200	Acute dermal	LD[50] > 5,000 mg/kg Toxicity Category IV
870.1300	Acute inhalation	The requirement for an acute

USDA United States Department of Agriculture

United St[ates] Environm[ental] Protection [Agency]

MEMORANDUM OF UNDERSTANDING

EPA/OPP and USDA/APHIS Process for Sharing Information on Herbicide Tolerant Crops

Since January 2000, the USDA and EPA have been identifying procedures that will improve coordination between the two agencies in their reviews of herbicide-tolerant crops and their respective herbicides. Currently, the APHIS reviews of the herbicide-tolerant crops and EPA reviews of the herbicide are done without any formalized joint reviews or sharing of information. For example, APHIS examines issues of gene flow / outcrossing to wild species and weediness, and EPA has information on current and future herbicide registration decisions.

The improved coordination being proposed will include an ad hoc interagency work group that would establish a protocol for exchanging completed scientific reviews between the agencies, whereby potential gaps and differences could be identified more readily, and more expertise could systematically be brought to bear in these analyses. This would also shorten the review time in some instances by providing insight and perspective when the two agencies are trying to answer very similar questions.

Specific coordination measures that can be implemented include the following: APHIS will provide EPA a copy of APHIS petitions for non-regulated status for herbicide-tolerant crops. During the preparation of its Environmental Assessments (EA), APHIS will consult with EPA, especially as to any discussions of available herbicides for a given crop and their practical utility, i.e., efficacy on key weed pests. To this end, EPA will supply APHIS with current lists of herbicides registered for use on the crop in question, and any readily available information as to their efficacy. APHIS would also supply the work group with copies of extensions to existing petitions. This would keep the work group informed of any new transformation events that encode the same herbicide-tolerant phenotype in a crop from the same registrant.

APHIS will ask each petitioner of herbicide-tolerant crops to submit a voluntary stewardship plan for the management of pest resistance and potentially weedy volunteer crops in their herbicide-tolerant crops and crop rotations. Since APHIS receives petitions from registrants of herbicide-tolerant crops far in advance of EPA's receiving an application for registration of the herbicide on that crop, APHIS will consult with EPA as to the viability of the stewardship plans while preparing the APHIS EA. Having the two agencies concur on a stewardship plan early on in the registration process will ensure that the concerns of both agencies are addressed, and that these concerns are discussed in the EA along with the details of the plan and its implementation. The opportunity for the public to comment on both the petition and EA ensures transparency in the joint review process. APHIS will, on an annual basis, keep EPA and the work group informed of what is in the registration pipeline by supplying a list of the herbicide-tolerant plants that are field tested each year. This advance notification system could alert the EPA to potential high-risk uses that might be of concern from an environmental or human health perspective.

The sharing of confidential Business information (CBI) between the EPA and APHIS will not be a problem. For more than a decade, APHIS employees have routinely been certified by EPA for handling FIFRA CBI information. EPA has procedures for protecting CBI information it receives from APHIS.

James J. Jones, Director Registration Division Office of Pesticide Programs/EPA	Mary Neal, Director Plant Health Programs Plant Protection and Quarantine/USDA

http://sl.farmonline.com.au/news/nationalrural/grains-and-cropping/general/smart-farming-essential-to-manage-resistance/1879228.aspx?storypage=0

Smart farming essential to manage resistance
BY GREGOR HEARD
Stock and Land - 13 Jul, 2010 02:11 PM

WITH glyphosate prices at rock-bottom levels, the temptation for Australian growers is to keep pouring on the popular herbicide rather than rotate chemical modes of action and use more expensive options.

According to leading international herbicide researcher Harry Strek, leader of Bayer Crop Science's integrated weed management and weed resistance biology team in Germany, it could be the most expensive cheap option they have ever taken.

He said the issue of herbicide resistance, across most of the major chemical groups, was already a big issue and was only going to get bigger, **citing research showing that by 2018, 50 per cent of agricultural weed species will be glyphosate resistant.**

And while Australia has yet to have significant problems with glyphosate resistance, there are already significant problems with Group A 'fops and dims' and Group B sulfonylurea resistance and emerging problems with trifluralin resistance meaning Australia has some of the highest instances of weed resistance in the world.

The ryegrass resistance to a range of herbicides that is an issue through many cropping zones in Australia was an example of Australia's resistance problems, Dr Strek said.

"You look at the work of Stephen Powles at the University of Western Australia on resistant ryegrass, he found that it was ideally suited to becoming resistant, as it was planted as a fodder crop over many acres and when the land was converted to grain production, there was a genetically diverse population with lots of outcrosses, so there was the resistant genetic material and through pollen, it travelled widely."

Dr Strek said resistant weeds were one of the biggest threats to cropping in the 21st century, especially in no-till systems becoming increasing popular in Australia, where there are few other options other than herbicide applications to control weeds.

"Weeds present a higher global threat to yield loss than even fungus and insect infections."

He said with issues of resistance in mind, a solid chemical rotation and an integrated weed management (IWM) strategy were critical in keeping chemical modes of action effective.

"Farmers must be smart about both their crop rotations, and by extension, their chemical rotations and using different chemistries.

"The surest way of getting herbicide resistant weeds is to continue to rely on the same mode of action for year after year.

"It's natural for farmers to keep using the same product if it is effective, but the key message is that there need to be different modes of action.

"You look at the example of glyphosate in the US, it's a tool that farmers love, but it is trouble because of that popularity and its overuse."

He said along with using different chemicals, a 'double knock' approach of using the usual herbicide along with another mode of action to ensure control of the population becoming resistant to the major group, was an effective strategy.

Crop rotations, timing of cropping and less fashionable management options such as cultivation were other methods to minimise issues.

However, Dr Strek was pessimistic about stopping the onslaught of resistant weeds altogether, even with sound management strategies.

"We used to talk about stopping resistance, now we are talking about slowing it down.

"Rotations will work well in slowing resistance down, and keeping that selection pressure, but there will be issues no matter what."

He said growers needed to understand how resistance worked, with most weeds controlled by the herbicide, but a small amount each generation that were not.

Each generation through the selection process, there were more of the plants with the resistance trait.

Dr Strek said along with management techniques, the hunt was on for new chemical modes of action, but warned the low-hanging fruit had well and truly been picked and it was a struggle to develop new lines.

"There have been no significant new modes of action developed for 20 years, you may get chemistry that is new to a particular crop or country, but nothing huge, and that is reflected by the fact six herbicide classes are responsible for 75pc of worldwide herbicide sales, and just three groups, the As, Bs and glyphosate represent 50pc of sales, and these three groups are under strong resistance pressures in many areas."

However, he said Bayer was continuing to invest in research.

"The success rate isn't what it was, but our research is more targeted, it is no longer a numbers game, its smarter and more focused and we believe we have some work that will yield something."

But, ultimately, Dr Strek said the frontline in battling resistance would be sound decision making from growers.

"IWM strategies, where crops and herbicides are rotated and there are different crop management strategies, whether it be cultivation, early or late sowing or fodder making, will be the best defence against resistant weeds."

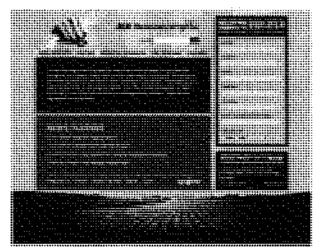
Leading the Fight against Glyphosate Resistance

Glyphosate weed resistance is a real and growing problem in U.S. fields. Since glyphosate-resistant horseweed (marestail) was first confirmed in row crops in 2000, **nine weeds** have been confirmed resistant to glyphosate in **20 states**.

"Syngenta estimates that more than **7 million row crop acres** were infested with glyphosate-resistant weeds last year," says Chuck Foresman, manager of weed resistance strategies for Syngenta. "With an expected 40 percent average compounded annual growth rate, we estimate that more than **38 million row crop acres** could be infested with glyphosate-resistant weeds by 2013, or one in every four acres."

Since 2001, Syngenta has been advising retailers and growers about the potential for glyphosate-resistant weeds, educating them on management strategies and developing solutions to control resistant weeds.

"Glyphosate is a one-in-100-year discovery," Foresman says. "Glyphosate-tolerant technology is worth preserving, and Syngenta has been encouraging growers and retailers to take steps to do that for years."



Syngenta hosts www.resistancefighter.com, a one-stop source for resistance management information, expert recommendations and solutions. The site features

- The Solution Builder, which creates practical, solutions customized by crop, weed, location, preferred management practices and history of resistance to fight glyphosate-resistant weeds based on answers to a few simple questions
- Answers to common glyphosate resistance questions
- University research and information
- Crop strategies to build a resistance management program
- The opportunity to join the conversation about glyphosate weed resistance, including the blog from Syngenta experts, articles and radio broadcast clips

"Resources, products and information are available to help equip growers to preserve yield potential and the value of glyphosate-tolerant systems," says Foresman. "A proactive, integrated weed management program that includes alternating modes of action and using a residual pre-emergence herbicide is the best strategy."

Syngenta ResistanceFighter.

Syngenta recommendations to manage glyphosate resistance include: Use pre-emergence residual herbicides in glyphosate-tolerant crops.

- Choose herbicides or tank mixes with multiple modes of action. Products like Bicep II Magnum®, Halex® GT, Lexar®, Lumax®, Prefix®, Boundary® and Flexstar® GT herbicides from Syngenta deliver multiple modes of action. Tank mixes also can provide multiple modes of action for weed control.
- Rotate crop and herbicide systems.
- Use full herbicide rates to reduce the chances of developing resistance.
- Scout fields and develop a multiyear weed resistance management plan.

These recommendations are supported by university weed scientists. And local Syngenta experts work with retailers and growers to address resistance in the field.

Syngenta is committed to preserving today's toolbox to manage weed resistance. The company's investment in research includes developing future strategies to delay resistance and preserve valuable technology like glyphosate-tolerant crops.

"Solutions are available," says Foresman. "It's all about arming yourself with the right tools, and at Syngenta, we have many of the tools needed to manage against glyphosate resistance."

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http://southeastfarmpress.com/cotton/heavy-residue-combats-resistant-pigweed-0622/

Heavy residue combats resistant pigweed
Jun 22, 2010 9:54 AM, By Jim Langcuster, Auburn University

In fact, traits that have enabled Palmer amaranth to develop resistance to glyphosate also render it more susceptible to the effects of high-residue crop systems.

While glyphosate-resistant pigweed may threaten the gains made in high-residue conservation-tillage cropping systems within the last couple of decades, many of the nation's crop scientists are not giving up without a fight.

HEAVY RESIDUE from a cover crop helps suppress herbicide-resistant Palmer amaranth.
In addition to their brains and expertise, they're adding another formidable weapon: Obstinacy, coupled with an abiding confidence that, come what may, they will be victorious in the end.

Andrew Price, a plant physiologist with the U.S. Department of Agriculture's National Soil Dynamics Laboratory based at Auburn University, says the loss of glyphosate use due to the growing presence of glyphosate-resistant Palmer pigweed is being felt acutely on some farms. Even so, he says this does not call for the abandonment of high-residue conservation-tillage practices.

(For more click here.)

Quite the contrary: Based on his own experience in researching high-residue cropping systems he says there is every reason to stick with these approaches — and not only for the advantages they provide in soil moisture retention and enhancing organic matter. High-residue systems also appear to be highly effective in suppressing weeds — and, as it turns out, Palmer amaranth, especially.

In fact, traits that have enabled Palmer amaranth to develop resistance to glyphosate also render it more susceptible to the effects of high-residue crop systems.

"Many small seeds, such as Palmer amaranth seeds, have specific light requirements in order to germinate," Price says. "Putting inches of residue on top of the seed prohibits light as well as other environmental cues required to germinate the weed, he says.

In adopting these high-residue cropping systems as a weed suppression strategy, Price says timeliness is of the essence.

The most successful farmers who have adopted these high-residue systems quickly follow harvest with a cover crop planting using a no-till drill, he says.

"They come in with the drill and within weeks have a cover crop," he says, adding that by getting an early start with a cover crop, farmers better ensure that sufficient biomass will be in place by the time the cash crop is ready to be planted.

Price is also advising producers to fertilize the cover crop at a rate of 30 pounds of nitrogen an acre, ideally in early spring to allow the cover crop to mature to ensure optimal levels of biomass.

"The goal should be not to terminate it (the cover crop) early, but to take it up as close as two to three weeks before the cash-crop planting," he says.

Price says this approach works especially well with peanuts and cotton, which can be planted comparatively later to allow the highest levels of biomass.

Corn, on the other hand, presents a challenge.

"Obviously, with corn, you're planting early, and that's a disadvantage in one respect because you're going to see less biomass."

Clover may be an option in some cases.

"As a legume, it doesn't offer the same advantages as rye as a cover crop, but it does have its merits," he says. "For example, with that system, you do have the advantage of certain effective herbicides, such as atrazine, a very efficacious herbicide in terms of preventing weed germination."

While a growing number of farmers are having success with these high-residue strategies, Price says there will be an added reliance on pre-emergent herbicides — one reason why he's encouraging farmers to adopt irrigation practices.

"Integrating these pre-emergent herbicides within irrigated systems is going to work much better in getting them activated," Price says. "The real problem with this approach comes with dryland systems where we don't get enough activation of pre-emergent herbicides."

Despite the success with these cropping systems, Price says he has turned up one irony: Minimal levels of tillage used in tandem with cover crops have proven effective in weed suppression.

"One of these (minimal-tillage systems) involves going in with fall tillage, burying the Palmer amaranth seed and then planting a high-residue cover crop without disrupting the soil.

"Tillage is something we typically want to see minimized, so in one sense we're presented here with a catch-22."

Center for Food Safety
660 Pennsylvania Ave., SE, Suite 302
Washington, DC 20003

September 21, 2009

Office of Pesticide Programs
OPP Regulatory Public Docket (7502P)
Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

RE: Registration Review; Glyphosate Docket Opened for Review and Comment.
Docket Number: EPA–HQ–OPP–2009–0361

To Whom It May Concern:

The Center for Food Safety appreciates the opportunity to submit comments re: the docket listed above.

I. Introduction

The purpose of the registration review program is to assess the risks that pesticides pose to human health and the environment in the light of new scientific information, enhanced ability to detect risks, changes in pesticide policy, and alterations in pesticide usage practices.

Since the EPA last reregistered glyphosate in 1993, there have been profound changes in the usage patterns of this pesticide. Overall and agricultural use of numerous glyphosate formulations has grown tremendously; the advent of transgenic glyphosate-resistant crops has permitted previously infeasible "over-the-top" application, raising novel food, feed, environmental and agronomic concerns; the unprecedented degree of reliance on this single weed control chemical in conjuction with the glyphosate-resistant crop system has fostered an epidemic of resistant weeds; animal and human exposure to glyphosate residues has increased sharply with a spate of new registrations as well as new and often greatly increased tolerances; and finally, rising use of glyphosate correlates to some degree with profound alterations in farming practices, in particular increasing use of conservation tillage/no-till.

The strong and still growing dependence of U.S. and world farmers on glyphosate is no doubt one important factor driving intense scientific study of this chemical. This scientific study has revealed much new evidence that glyphosate and its formulations (especially those with the surfactant POEA) poses serious risks to human health and the environment, including the agricultural environment. We note that in general, any risks posed by a particular pesticide will be amplified and exacerbated with increasing use, and that it is only rational to take full account of this factor in risk assessments. On the policy front, EPA has played an important role in facilitating increased glyphosate use by issuing new registrations and new and increased tolerances, and by failing to establish resistance management regulations or even guidelines to stem the epidemic of glyphosate-resistant weeds.

In these comments, we will first describe the profound changes in glyphosate use patterns, including a prospective assessment of further changes to be expected in the near future. We will then describe new evidence of ecological/agronomic risks and human health risks.

II. Glyphosate Usage Trends: Past and Prospective

The EPA rightly emphasizes the importance of assessing changes in the usage patterns of a pesticide in its registration review (Summary Document, p. 4). Though the Agency does not explain why this is important, the rationale should be clear. A pesticide with adverse effects will obviously have adverse impacts that correlate with its use – greater and more widespread usage means greater impacts. Thus, a highly toxic pesticide that is very little used may well have much less overall adverse impact than a heavily-used pesticide that is less toxic. It is equally clear that suggestive evidence of harm from a pesticide (i.e. not fully confirmed) should be given greater weight in the risk assessment process in rough proportion to the prevalence and level of use of that pesticide. The history of pesticides, drugs and other chemicals is filled with examples of hazardous substances whose widespread use was allowed to continue for decades in the face of strong suggestive evidence of harm that was eventually confirmed, resulting in massive human suffering and ecological degradation that could have been avoided had appropriate restrictions been enacted before definitive conclusions were reached. Dioxin-containing pesticides and other chemicals, indiscriminate use of DDT, PCBs, and lead in paint and gasoline are a few of many such examples.

Yet surprisingly, none of the Agency's review documents in Docket EPA-HQ-OPP-2009-0361 makes any reference to changes in the usage of glyphosate over the past 15 years, much less gives a prospective assessment of future trends. This is especially concerning in light of the accumulating evidence of the adverse impacts of glyphosate and its formulations, and the fact that over this period, ***glyphosate has become by far the most widely used pesticide in the history of agriculture***. This is a serious failing in the Agency's work plan that we hope will be remedied as the registration review proceeds.

We begin by describing the reasons for and the magnitude of the explosive growth in glyphosate's use. Glyphosate was first registered in 1974. By 1987, its agricultural usage was still limited mainly to orchards, and with an estimated 6 to 8 million lbs. active ingredient ranked just 17^{th} among pesticides in terms of quantity applied for U.S. agricultural crop production (see Figure 1). Three major developments in agriculture have expanded its use.

1) Glyphosate for Burndown Use

First, increasing adoption of conservation tillage/no-till cultivation practices in major field crops, especially in soybeans, drove greatly increased applications of glyphosate for burndown use in the late 1980s and the 1990s. In no-till cultivation, crops are killed chemically (burnt down) at the end of the season, and the following year's seeds are drilled through crop stubble, rather than the traditional plowing under of crop residues. Glyphosate quickly became the herbicide of choice for such applications, facilitating its rapid adoption in field crop cultivation. This is the main factor driving the four- to six-fold increase in agricultural use of glyphosate from 1987 (6 to 8 million lbs.) to 1997 (34 to 38 million lbs.) (Figure 1).

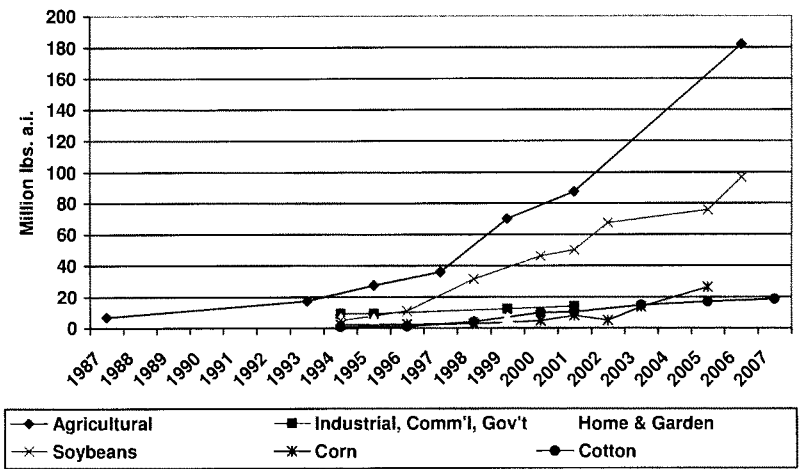
2) Glyphosate Use with Glyphosate-Resistant Crops

a) Roundup Ready Soybeans and Cotton

The second major factor driving increased glyphosate use has been the widespread adoption of transgenic, glyphosate-resistant soybeans, cotton, and corn by farmers beginning in 1996, 1997 and 1998, respectively. While glyphosate had previously been restricted mainly to orchard use and burndown applications in field crops, glyphosate-resistance facilitated "over-the-top" or in-field application of this broad-spectrum herbicide that had previously been infeasible. Glyphosate-resistant (GR) varieties of soybeans and cotton were rapidly adopted, rising to comprise 75% of the soybean acres (USDA NASS figure) and 72%[1] of the cotton acres planted in 2002. Figure 2 shows that Roundup Ready (RR) crops, planted on just 1.2 million acres in 1996 (all RR soybeans), covered a massive 78.7 million acres just six years later in 2002 (Figure 2).[2] This huge growth in RR crop acreage coincides with, and was undoubtedly the chief factor driving, a substantial acceleration in the growth rate of glyphosate use. In the decade from 1987 to 1997 (largely prior to the advent of RR crops), agricultural glyphosate use rose by an average of 2.9 million lbs. a.i. per year. In the four years from 1997 to 2001, the average annual growth rate had more than quadrupled, to 12.9 million lbs. per year (i.e. 36 to 87.5 million lbs.).[3] Figures 1 and 2 illustrate clearly that glyphosate use associated with RR soybeans is the most important factor driving the overall increase in agricultural glyphosate use during this period. Thus, it is no surprise to find EPA figures showing that by 2001, glyphosate had surpassed atrazine to become the most heavily used agricultural pesticide in the nation (EPA 2004, Table 3.6).

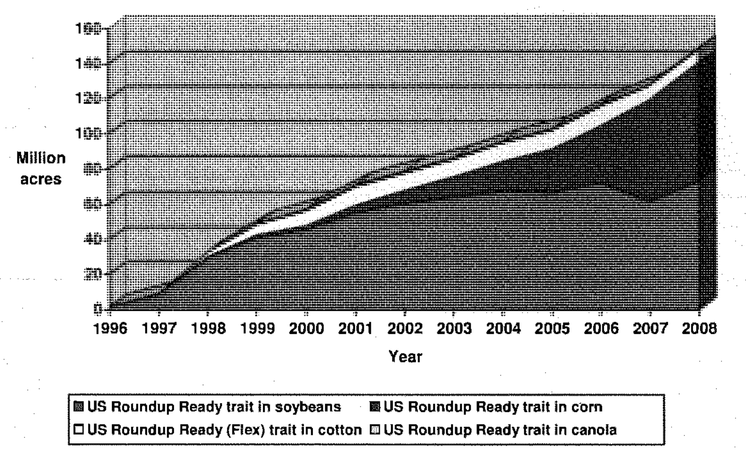
[1] May, O.L., F.M. Bourland and R.L. Nichols (2003). "Challenges in Testing Transgenic and Nontransgenic Cotton Cultivars," *Crop Science* 43: 1594-1601, Table 1. http://crop.scijournals.org/cgi/reprint/43/5/1594.pdf. Note that May et al cite USDA AMS figures for cotton that are more reliable than USDA NASS re: GE crop adoption.
[2] Based on Monsanto's figures. The breakdown is RR soybeans (60 million acres), RR cotton (10 million), RR corn (7.8 million) and RR canola (0.9 million). Since canola is a relatively minor crop for which consistent data are lacking re: glyphosate use, we exclude it from the subsequent discussion.
[3] Note that EPA figures for glyphosate use are given in ranges: e.g. 34 to 38 million lbs. (1997) and 85 to 90 million lbs. (2001). We have used the midpoint of these ranges for simplicity's sake.

Figure 1: Use of Glyphosate in the U.S. by Category and Field Crop: 1987 to 2005-2007



EPA figures 1987 to 1995 from EPA (1997). "Pesticides Industry Sales and Usage: 1994 and 1995 Market Estimates," EPA, August 1997, Tables 8 & 9; EPA figures 1997, 1999 & 2001 from EPA (2004). "Pesticides Industry Sales and Usage: 2000 and 2001 Market Estimates," EPA, May 2004, Tables 3.6 to 3.8. Each data point is the midpoint of the range (e.g. 27.5 for 25-30 million) given in EPA (1997) and EPA (2004). EPA figure for 2006 derived from EPA (2009). "Glyphosate Summary Document Registration Review: Initial Docket," June 2009, p. 12, which states that 135 million lbs. glyphosate acid equivalents are applied annually to agricultural crops, based on data from Screening Level Estimates of Agricultural Uses of the Case Glyphosate, 11/26/08. Acid equivalents converted to the most common salt of glyphosate (isopropylamine) using 0.74 conversion factor to arrive at the equivalent figure for the isopropylamine salt of glyphosate (182 million lbs.) to facilitate comparison to prior years. EPA leaves unclear in which year this estimated 135 a.e./182 a.i. million lbs. of glyphosate were applied. Comparison of EPA's figures for soybeans, corn and cotton in the Screening Level Estimates with the latest available from USDA NASS for soybeans (2006), corn (2005) and cotton (2007) suggests that EPA relied primarily on these USDA NASS data. We choose 2006 as the midpoint of this three year (2005-2007) range, and because soybeans, surveyed in 2006, receive the most glyphosate. See text for explanation as to why this figure likely underestimates actual glyphosate use, which CFS estimates at 210-220 million lbs. a.i. (iso.). Glyphosate use figures for soybeans, corn and cotton derived from USDA NASS Agricultural Chemical Usage reports for respective years, adjusted to reflect usage on 100% of crop acreage.

Figure 2: U.S. Acreage Planted to Crops with Roundup Ready Trait: 1996 to 2008



Source: Monsanto Biotechnology Trait Acreage: 1996-2008, Oct. 8, 2008.

b) Roundup Ready Corn

Despite this extremely rapid and accelerated rise in glyphosate use from 1997 to 2001, the years ***since*** 2001 have seen not only continued growth, but ***a substantial acceleration in the rate at which agricultural glyphosate use has increased***. Based on EPA's figures, agricultural use of glyphosate rose from 87.5 million lbs. in 2001 to 182 million lbs. by 2006,[4] an average annual growth rate of 18.9 million lbs. over this period (Figure 1). The major factors driving this accelerated use are glyphosate usage associated with increasing adoption of Roundup Ready corn, and the rapid emergence of weeds tolerant or resistant to glyphosate.

Figure 3 shows that adoption of RR corn was relatively slow through 2002, but has accelerated ever more rapidly since that time through 2007, with a slightly less pronounced increase from 2007 to 2008. The 68.3 million acres planted to corn containing the Roundup Ready trait in 2008 represents nearly a nine-fold increase over the 7.8 million RR trait-containing acres in 2002, and a more than 3-fold increase over the 24.8 million acres of RR corn in 2005. This huge increase in RR corn acres has been accompanied by a corresponding rise in glyphosate use. For instance, USDA NASS data show a more than five-fold increase

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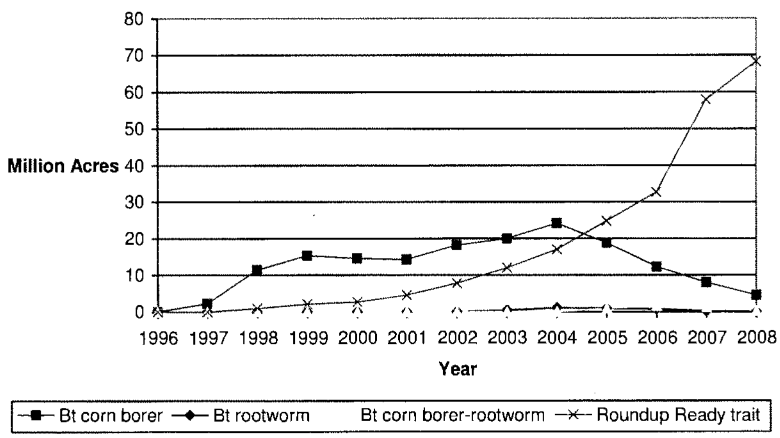
[4] For conversion of 135 million lbs. glyphosate a.e. to 182 million lbs a.i. (isopropylamine salt), see caption to Figure 1. As explained further below, we believe this 182 million lbs. a.i. figure is a substantial underestimate attributable to a large underestimate of glyphosate use on corn.

in glyphosate use on all U.S. corn from 2002 (5.1 million lbs.) to 2005 (26.3 million lbs.). It is interesting to note that glyphosate use on corn rose considerably faster (five-fold) than RR corn acres (3-fold) from 2002 to 2005.

Figure 3: Area in U.S. Planted to Monsanto GM Corn with Bt Trait(s) Alone vs. Varieties with Roundup Ready Trait: 1996-2008



Source: Monsanto Biotechnology Trait Acreage: 1996-2008, Oct. 8, 2008.

Since 2005, RR corn adoption has risen still more rapidly, nearly tripling from 24.8 to 68.3 million acres. Unfortunately, USDA NASS has not collected pesticide usage data for corn since 2005, so we do not know how much more glyphosate use is associated with the rapid rise in RR corn adoption. A conservative estimate would have glyphosate use on corn rising by the same factor as RR corn acres (recall that from 2002 to 2005, glyphosate use rose much more rapidly than RR corn acres). Multiplying 26.3 million lbs. (2005 glyphosate use on corn) by 2.75 (the factorial rise in RR corn acres from 2005-2008, 68.3/24.8) gives an estimated 72 million lbs. of glyphosate use on corn in 2008. This is more than double EPA's figure for glyphosate use on corn in the Screening Level Estimates of 30.4 million lbs. a.i.[5] EPA's substantial underestimate of glyphosate use on corn is likely due to reliance on the USDA NASS figure for 2005 (the latest available), when much less RR corn was grown, and perhaps to EPA's failure to adjust USDA NASS survey figures to account for glyphosate applied to 100% of crop acreage. EPA is urged to reevaluate its estimate for glyphosate use

[5] 30.4 million lbs. is derived by converting the cited glyphosate acid equivalent figure of 22.5 million lbs. to lbs. of active ingredient in the most common salt form of glyphosate (isopropylamine) using the conversion factor for the isopropylamine salt, 0.74.

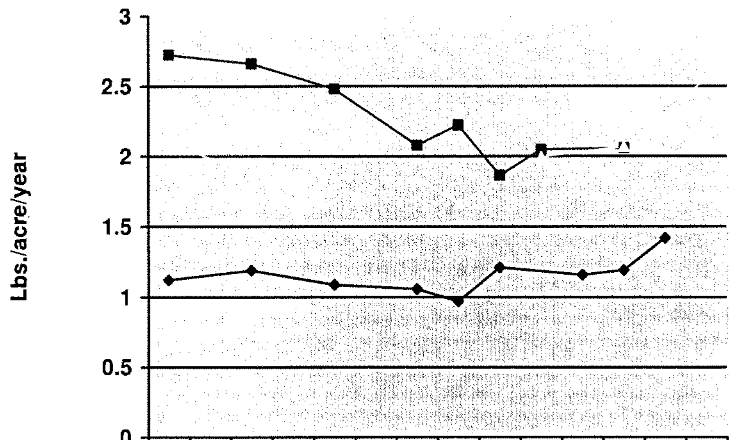
on corn to account for the dramatic rise in RR corn acres since 2005. Using the revised estimate suggested above for glyphosate use on corn of roughly 70 million lbs. a.i., overall agricultural glyphosate use would now stand at approximately 220 million lbs. a.i. rather than the EPA's estimated 182 million lbs a.i.

3) Glyphosate Use Fosters Weed Shifts and Glyphosate-Resistant Weeds

An even more important factor in the continuing rise in glyphosate use is the rapid emergence of glyphosate-resistant and glyphosate-tolerant weeds (from weed shifts) since the year 2000. For more on weed shifts and glyphosate-resistant weeds and how they have driven increased glyphosate (and overall herbicide) use, see Appendix 1. Here, we note merely that overall herbicide usage rates (lbs./acre/year) have risen dramatically on soybeans and cotton, the crops most infested with GR weeds, since GR weeds exploded onto the scene in 2000-2001 (Figure 4). In the case of soybeans, average herbicide intensity has risen by 46% from 2001 (0.97 lbs./acre/year) to 2006 (1.42 lbs./acre/year), while in cotton there has been a 54% increase in herbicide intensity from 2001 to 2007 (1.66 lbs/acre/year to 2.56 lbs./acre/year).

Closer analysis of the data reveals that these substantially higher herbicide usage rates for soybeans and especially cotton since 2001 are comprised of increased glyphosate usage rates and roughly constant rates for the category of non-glyphosate herbicides. Based on these observations with soybeans and cotton, the pattern of herbicide use with increasing adoption of glyphosate-resistant crops is: first, displacement of other herbicides by glyphosate until RR versions become predominant (roughly 75% of overall crop acreage); then, continuing large increases in glyphosate use with constant use (overall) of non-glyphosate herbicides, as the growing number of farmers plagued by GR weeds and glyphosate-induced weed shifts lead to increased annual glyphosate usage rates (chiefly increased number of applications per year, but rising rates per application as well). We note that as of 2009, RR corn still comprises "only" about 60% of all corn acreage. If this pattern is repeated with corn, as seems likely, the near-term future will see continuing substantial rises in glyphosate use.

Figure 4: Herbicide Use on Major Field Crops in the U.S.: 1994 - 2007



	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Soybean	1.123		1.19		1.087		1.058	0.97	1.21		1.158	1.191	1.42	
Corn	2.724		2.662		2.48		2.08	2.223	1.865	2.049		2.061		
Cotton	2.082		1.893		1.854		1.842	1.664		1.996		2.071		2.56

Year

Soybean — Corn — Cotton

Notes: Herbicide use rates began rising in 2002 for soybeans and cotton, as GE herbicide-resistant versions of these crops became prevalent (reaching 75% and 74% of overall crop acreage, respectively, in 2002). Herbicide use on corn rose slightly in 2003, but no trends apparent as of 2005, the last year for which we have data.

Sources: "Agricultural Chemical Usage: Field Crops Summary," USDA National Agricultural Statistics Service, for the respective years. See: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1560. The figures represent total herbicide use on the respective crop in the "Program States" included in USDA's survey, divided by the number of acres planted to that crop in the Program States. The Program States surveyed by USDA represent a high percentage of nationwide acreage planted to the crop (usually more than 80%, often more than 90%). The only assumption made here is that the amount of herbicides applied per acre covered by the survey is equal to that applied on acres not included in the survey. This is accepted practice for calculation of pesticide usage rates. For instance, compare Table 3.3.3 in Section 3.3: "Biotechnology and Agriculture," in: "Agricultural Resources and Environmental Indicators, 2006 Edition," USDA Economic Research Service, Economic Information Bulletin 16, July 2006, accessible from: http://www.ers.usda.gov/Publications/AREI/EIB16/. In this 2006 report, USDA for some unexplained reason plotted pesticide use on major field crops only up through 2001 or 2002, despite the availability of data for later years.

4) Prospective Assessment of Glyphosate Use

A prospective assessment of glyphosate usage patterns must take several factors into consideration, including: a) Potential for increased glyphosate use with expanded acreage of GR crops; and b) Potential for increased glyphosate usage rates (i.e. lbs./acre/year) from introduction of newer GR varieties with enhanced glyphosate-resistance and/or broadened application windows, and in response to weed shifts to more glyphosate tolerant weed species and continued evolution of GR weeds.

a) GR crop acreage and associated glyphosate use will continue to rise

High adoption rates of glyphosate-tolerant soybeans and cotton (>=90%) suggest modest, but not negligible, potential for increased glyphosate use from expansion in acreage planted to GR versions of these crops. GR corn adoption, however, was "only" roughly 60% of U.S. corn acres in 2009, and will likely continue to rise in the near future. Introduction of GR alfalfa (4th most widely planted crop in the U.S.), which is presently pending deregulation by USDA, would add considerably to overall GR crop acreage and increase glyphosate use correspondingly. Introduction of GR wheat (3rd most widely planted crop in U.S.) would spur glyphosate use still more, as would the pending deregulation of GR bentgrass. Any significant GR adoption rate of these widely planted crops and grass would add considerably to overall glyphosate use.

Another factor to consider in any near-term assessment of glyphosate use patterns is the spate of new GR crops developed by Monsanto's competitors. DuPont-Pioneer obtained deregulated status for its glyphosate-resistant Optimum GAT soybeans, while GR Optimum GAT corn is pending deregulation with USDA. Bayer has obtained deregulated status for its GR Glytol cotton, and a new version of GR corn from Stine Seeds is pending deregulation. Expanded marketplace offerings of GR crops by Monsanto's competitors may well drive increased adoption, even in crops with already-high adoption rates (soybeans, cotton). We note that such GR crop adoption rate increases could be partly demand-driven, but will also likely be in part supply-driven. Supply-driven increases in GR crop adoption rates are attributable to the "trait penetration" strategy of Monsanto and other biotech seed suppliers. Trait penetration is the profit-driven strategy of loading as many traits as possible into seed varieties, and retiring or cutting back supplies of conventional seeds and seeds with fewer traits. It is beyond the scope of these comments to discuss this matter in any detail, but there is considerable evidence to suggest that trait penetration is currently focused chiefly on introducing the glyphosate-resistance trait into corn. The steep rise in RR trait-containing corn acres over the past four years is at least partly the result of Monsanto's implementation of this strategy (Figure 3). Even farmers who "unwillingly" purchase a variety of corn seed with glyphosate resistance (due to lack of desirable/suitable varieties without the GR trait) may well make use of the GR trait through "over-the-top" use of glyphosate.

The medium- to long-term projection of glyphosate use associated with expanded GR crop acreage is more difficult. Some evidence for such an assessment can be gleaned from USDA's database of field trial permits for genetically engineered crops. CFS undertook an analysis of this database on April 7, 2009.[6] As of that date, there were 812 active permits issued by USDA for GE crop field trials; 283 or 35% involved herbicide-resistant (HR) crops (some of these permits authorized field-testing of other traits in addition to herbicide resistance). Since some field trial permits authorized field testing of various single-trait HR plants each resistant to different herbicides (e.g. some glyphosate-resistant, others dicamba-resistant), the total number of HR phenotypes was 327. Still other permits involved combinations of 2 or 3 HR traits in the same plant (23 and 4 permits, respectively); when these HR traits are counted separately, the total number of HR traits comes to 358. Of these 358 HR traits, 164 (46%) were glyphosate-resistance, and included GR alfalfa, corn, onion, canola/rapeseed and soybeans. There are no deregulated GR versions of either alfalfa or onion. In the case of field trials of herbicide-resistant creeping bentgrass and tobacco, one or more permits did not specify the herbicide to which the crop is resistant, thus these may also involve glyphosate-resistance.[7] Thus, two and perhaps as many as four glyphosate-resistant crops for which no GR versions are currently deregulated are currently undergoing field tests. This indicates at least modest medium- to long-term potential for increased glyphosate use associated with the introduction of new GR crops.

b) Enhanced resistance to glyphosate

A more important factor driving increased glyphosate use is the introduction of GR crops with increased levels of glyphosate-resistance and/or broader application windows for application of glyphosate. This development is being driven by the rapid expansion of glyphosate-tolerant and glyphosate-resistant weeds (which can still often be controlled, in the short term, by increased application rates of glyphosate and additional glyphosate applications). To our knowledge, this was first seen with the 2006 introduction of Monsanto's Roundup Ready Flex cotton, the successor to its original RR cotton.[8] The label for Roundup Ready Flex cotton recommends 1.5 times the application rate of that applied to original RR cotton (32 ounces/acre for Flex vs. 22 ounces/acre for original RR cotton).[9] With original RR cotton, the CP4 EPSPS enzyme (RR trait) was not expressed in reproductive tissues, limiting the "application window" to the immature plant. RR Flex cotton expresses the enzyme in reproductive tissues, permitting application of glyphosate to mature plants as well. With RR Flex cotton, farmers are enabled to wait until weeds become larger before applying glyphosate; larger weeds require higher application rates to kill, and are also more likely to flower and set seed. Any glyphosate-resistant weeds that are allowed to flower and set seed can then spread the resistance trait in two ways: 1) Spatially, through

[6] Two searches conducted at http://www.isb.vt.edu/cfdocs/fieldtests1.cfm. All active permits for GE crop field trials determined on 4/7/09 by checking the "phenotype category" on first page, then selecting all phenotype categories and "field test permits currently in effect" and "short record" on the next page. For active HT crop field trials, search conducted on 4/5/09 by checking "phenotype category" on first page and "herbicide-tolerance," "field test permits currently in effect" and "full record" on the next webpage. Permits with "status" of "withdrawn" or "denied" were excluded from the analysis of both total active field trials and active HT crop field trials.
[7] For some unexplained reason, fully 29% (105) of the HT traits being tested in field trials of GE crops as of April 7, 2009 were not specified in USDA's database. These traits were either labeled CBI ("confidential business information") or simply not specified.
[8] Bennett, D. (2005). "A look at Roundup Ready Flex cotton," *Delta Farm Press*, 2/24/05, http://deltafarmpress.com/news/050224-roundup-flex/.
[9] See Monsanto 2008 Technology Use Guide, pdf pages 31 and 34.

cross-pollination with susceptible weeds; and 2) Over time, by leaving weed seeds bearing the resistance trait in the seed bank to sprout in subsequent seasons. Introduction of RR Flex cotton may well have contributed to the steep (24%) increase in herbicide use on cotton from 2005 to 2007 (see Figure 4).

USDA's APHIS recently deregulated Bayer CropScience's GlyTol cotton (event GHB614), which incorporates still another new mechanism of glyphosate resistance.[10] Bayer informed APHIS that the company did not request a glyphosate label change with EPA and is using the current label application rate of glyphosate on their GHB614 product.[11] However, Cheminova, Inc., a manufacturer of glyphosate and other pesticides based in Denmark, applied for and recently obtained from EPA a tolerance increase for residues of glyphosate on cotton gin byproducts (from 175 to 210 ppm) that was specifically linked to introduction of GlyTol cotton.

> "Cheminova, Inc. has requested a Section 3 registration under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) for application glyphosate to glyphosate-tolerant cotton including Bayer GHB614 cotton (GlyTol cotton), a genetically modified cotton being commercialized by Bayer Crop Science. As a result, the petitioner has requested that the current tolerance for cotton, gin byproducts be increased to 210 ppm."[12]

In this same FR notice, EPA also refers to an Agency review entitled "Glyphosate Label Amendment to Permit Application of Glyphosate to Bayer's Glyphosate-Tolerant Cotton GHB614."[13] Thus, it appears that introduction of Bayer's GlyTol cotton requires both a tolerance increase and a glyphosate label amendment, suggesting that higher rates of glyphosate will be applied to this glyphosate-tolerant cotton; otherwise, there would seem to be little reason to seek and obtain a tolerance increase. The preexisting glyphosate tolerance for cotton gin byproducts was 175 ppm, which itself represents an increase from the corresponding tolerance prevailing in 2000 of 100 pm.

The increased glyphosate application rates and tolerances associated with GR cotton are consistent with the fact that GR weeds have posed a particular threat to cotton-growing areas in the U.S. Soybeans and corn are also increasingly infested with GR and glyphosate-tolerant weeds.

DuPont-Pioneer's Optimum GAT soybeans and corn (the former already deregulated, the latter pending deregulation by USDA)[14] contain a new mechanism of glyphosate resistance,

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[10] See USDA website listed above, petition 06-332-01p. For CFS comments, see: http://www.centerforfoodsafety.org/pubs/Bayer%20GlyTol%20Cotton%20Comments%20-%20CFS%20FINAL%208-18-08.pdf.

[11] APHIS (2009). "Determination of Non-regulated Status for Glyphosate-Tolerant (GlyTol) Cotton, Gossypoium hirsutum, event GHB614: Final Environmental Assessment, April 15, 2009, Response to Comments section, p. 24.

[12] EPA (2009). "Glyphosate; Pesticide Tolerances," FR Vol. 24, No. 120, June 24, 2009, pp. 29963-29996.

[13] Id., p. 29964.

[14] USDA Petitions for Nonregulated Status and any (draft) environmental assessments (EA) by USDA's APHIS are listed at http://www.aphis.usda.gov/brs/not_reg.html. DuPont-Pioneer's corn is petition 07-152-01p. For fuller discussion of this dual-HR corn, see also: "Comments to USDA APHIS on Environmental Assessment for the Determination of Nonregulated Status for Pioneer Hi-Bred International, Inc. Herbicide Tolerant 98140 Corn,"

different than Roundup Ready. GAT stands for glyphosate acetyltransferase, which inactivates glyphosate by adding an acetyl group to it. One report by DuPont scientists suggests that GAT corn may survive six times the normal dose of glyphosate "with no adverse symptoms."[15] This would permit higher doses of glyphosate (whether officially permitted by the label or not).

In a patent, DuPont-Pioneer proposes to "stack" GAT with one or both of Monsanto's mechanisms of glyphosate-resistance (CP4 EPSPS and GOX [glyphosate oxidoreductase]) in order to enhance tolerance to glyphosate still more and so enable applications of higher rates to kill increasingly resistant weeds.

> "A transgenic plant or transgenic plant explant having ***an enhanced tolerance to glyphosate***, wherein the plant or plant explant expresses a polypeptide with glyphosate-N-acetyltransferase activity... and ***at least one polypeptide imparting glyphosate tolerance by an additional mechanism***."[16] (emphasis added)

In a second patent issued to DuPont-Pioneer, the authors cite two examples of glyphosate application to soybeans incorporating dual glyphosate resistance comprising both DuPont-Pioneer's GAT mechanism and Monsanto's CP4 EPSPS mechanism. Glyphosate application totalled roughly 3 lbs. a.i. per acre per season in two applications in Example 1; and 4 lbs. a.i. per acre per season in one application in Example 2.[17] These application rates represent more than double to triple the average amount of glyphosate applied to glyphosate-treated soybeans in the U.S. in 2006 (1.33 lbs./acre/year, the figure for most the commonly used isopropylamine salt), according to USDA NASS's Agricultural Chemical Usage Report for that year. This 2006 figure already represents a huge increase over the average glyphosate usage rate prevailing before GR soybeans were first introduced (e.g. 0.52 lbs./acre/year in 1994).

Likewise, a biotech startup company in North Carolina, Athenix, is also developing a bacterial gene to confer enhanced glyphosate tolerance in crops.[18]

These examples show clearly the strong near-term potential for greatly increased glyphosate use associated with enhanced glyphosate tolerance in cotton, soybeans and corn, a development being driven by the rapid expansion of glyphosate-tolerant and –resistant weeds fostered by current GR crop systems.

Center for Food Safety, February 6, 2009, http://www.centerforfoodsafety.org/pubs/CFS%20comments%20on%20Pioneer%20HT%2098140%20corn%20EA_final_2_6_09-FINAL.pdf.

[15] Castle et al (2004). "Discovery and directed evolution of a glyphosate tolerance gene," *Science* 304: 1151-54. For discussion, see CFS comments cited in last footnote.

[16] "Novel Glyphosate-N-Acetyltransferase (GAT) Genes," U.S. Patent 2005/0246798, issued Nov. 3, 2005, assigned to: Verdia, Inc. and Pioneer Hi-Bred International, see claim 111, p. 89.

[17] "Novel Glyphosate-N-Acetyltransferase (GAT) Genes," U.S. Patent Application Publication, Pub. No. US 2009/0011938 A1, January 8, 2009, paragraphs 0152 & 0154. In Example 1, glyphosate was applied as follows: 840 grams a.e./ha 24 days post-plant and 1680 grams a.e./ha 44 days post-plant, for a total of 2520 grams. In Example 2, glyphosate was applied at 3360 grams a.e./ha 31 days post-plant. Conversion made from grams a.e. per hectare to pounds a.i. (isopropylamine salt) per acre in each case.

[18] Service, R.F. (2008). "A growing threat down on the farm," *Science* 316: 1114-1117.

The medium- to long-term potential for increased glyphosate use associated with enhanced glyphosate resistance is suggested by the predominance of glyphosate resistance among active GE HR crop field trial permits. As noted above, nearly half (46%) of HT crop traits in active field trial permit listings are glyphosate resistance. It is likely that some or most of these GR crop traits involve enhanced glyphosate resistance.

5) Glyphosate Usage Patterns: Summing Up

Glyphosate use has been driven by burndown use associated with no-till crop production, widespread introduction of glyphosate-resistant crop systems, and a growing epidemic of glyphosate-tolerant (weed shifts) and glyphosate-resistant weeds. Already the most heavily used pesticide in the U.S. by 2001, agricultural glyphosate use has not only grown further since then, but its rate of increase has actually increased since 2001. Today, it is by far the most widely used pesticide in the history of agriculture. Present use patterns are clearly unsustainable, yet a prospective assessment suggests continued growth in glyphosate use in the near- and medium-term future – driven by increased acreage of GR crops and even more importantly by the intertwined phenomena of shifts to more glyphosate-tolerant weed species and continued rapid evolution of GR weeds, on the one hand, and the development and introduction of newer GR crops with enhanced glyphosate resistance in response, on the other.

CFS urges EPA to fully describe glyphosate usage patterns since the last reregistration in 1993, and offer a prospective assessment as well. Specifically, the Agency should:

1) Include quantitative assessments of home and garden as well as commercial, industrial and government uses of glyphosate, which are totally absent in EPA's background documents

2) Revise its estimate of agricultural glyphosate use, through:
   a) Use of USDA NASS figures adjusted for 100% of crop acreage, rather than simply citing the glyphosate applied to surveyed acres;[19]
   b) Revision of the estimate of glyphosate use on corn, taking account of the glyphosate use increase driven by the substantial increase in RR corn acreage since 2005; as explained above, glyphosate use on corn is likely at least double (60-70 million lbs. a.i. (iso.)) that estimated by EPA;
   c) Express all glyphosate usage figures in lbs. of active ingredient, using the most common salt of glyphosate (isopropylamine), rather than acid equivalents. The conflicting usage of acid equivalents for the Screening Level Estimates and the total amount of glyphosate used, versus use of active ingredient (salt) figures for all other references (e.g. Appendix A of the Registration Review – Preliminary Problem Formulation for the Ecological Risk and Drinking Water Exposure Assessments for Glyphosate and its Salts) gives rise to needless confusion.

[19] In "Screening Level Estimates of Agricultural Uses of The Case Glyphosate," EPA inexplicably excludes glyphosate use on acres not surveyed, which can give rise to substantial underestimates, and is contrary to accept practice, which is to assume that the average use on surveyed acres applies to non-surveyed acres.

III. Ecological Threats Posed by Glyphosate

1) Toxicity of Glyphosate Formulations, Especially to Amphibians

The Center for Food Safety welcomes EPA's plan to examine more data on glyphosate formulations, especially those containing the surfactant polyethoxylated tallow amine (POEA), with respect to ecological risks. However, we urge the Agency to expand this assessment in several ways. First, the Agency should give full consideration to the numerous existing studies demonstrating substantial mortality of several species of amphibians (aquatic and terrestial phase) following exposure to glyphosate formulations containing POEA in outdoor mecocosms at field-relevant usage rates.[20] Rick Relyea's research team is just one of several that have found serious adverse impacts of Roundup on amphibians at environmentally relevant concentrations, as evidenced by the studies listed in the excerpt below from a letter to *Ecological Adapations*:[21]

> For example, Chen et al. (2004:828)[22] studied zooplankton and tadpoles and concluded, ''concentrations equal to and less than the EEC [expected environmental concentrations] were significantly toxic to both species. This suggests that both groups may be at risk of direct mortality at environmentally relevant concentrations.'' Edginton et al. (2004:821)[23] state, ''We concluded that, at EEC levels, there was an appreciable concern of adverse effects to larval amphibians in neutral to alkaline wetlands. The finding that the mean pH of Northern Ontario wetlands is 7.0 further compounds this concern.'' Even Thompson et al. (2004:848)[24] conclude that, ''Overall, results of this tiered research program confirm that amphibian larvae are particularly sensitive to Vision [i.e., Roundup] herbicide and that these effects may be exacerbated by high pH or concomitant exposure with other environmental stressors.'' Howe et al. (2004:1933)[25] state, ''The present results indicate that formulations of the pesticide glyphosate that include the surfactant POEA at environmentally relevant concentrations found in ponds after field applications can be toxic to the tadpole stages of common North American amphibians.'' My experiments concur with the conclusion that Roundup with POEA can be highly lethal to tadpoles at environmentally relevant concentrations.

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[20] For instance, see: Relyea, R.A. (2005a). "The lethal impact of Roundup on aquatic and terrestial amphibians," *Ecological Applications* 15(4): 1118–1124; Relyea et al (2005). "Pesticides and amphibians: The importance of community context," *Ecological Adaptations* 15: 1125-1134; Relyea, R.A. (2005b). "The letal impacts of Roundup and predatory stress on six species of North American tadpoles," *Archives of Environmental Contamination and Toxicology* 48: 351-57

[21] Relyea, R.A. (2006) in: *Ecological Adaptations* 16(5): 2027-2034.

[22] Chen, C. Y., K. M. Hathaway, and C. L. Folt (2004). "Multiple stress effects of Visiont herbicide, pH, and food on zooplankton and larval amphibian species from forest wetlands," *Environmental Toxicology and Chemistry* 23: 823–831.

[23] Edginton, A. N., P. M. Sheridan, G. R. Stephenson, D. G. Thompson, and H. J. Boermans (2004). "Comparative effects of pH and Vision herbicide on two life stages of four anuran amphibian species," *Environmental Toxicology and Chemistry* 23: 815–822.

[24] Thompson, D. G., B. F. Wojtaszek, B. Staznik, D. T. Chartrand, and G. R. Stephenson (2004). "Chemical and biomonitoring to assess potential acute effects of Vision herbicide on native amphibian larvae in forest wetlands," *Environmental Contamination and Toxicology* 23: 843–849.

[25] Howe, C. M.,M. Berrill, B. D. Pauli, C. C. Helbring, K.Werry, and N. Veldhoen (2004). "Toxicity of glyphosate-cased pesticides to four North American frog species," *Environmental Toxicology and Chemistry* 23: 1928–1938.

The need for EPA to thoroughly investigate Roundup's risk to amphibians and take appropriate actions is especially urgent give the lack of data on Roundup's risk to amphibians in the Agency's 1993 risk assessment; the vastly increased use of glyphosate/Roundup since 1993, as documented above; the possible link between glyphosate/Roundup use and the global amphibian crisis that has developed over the past 15 years; and finally, the Agency's own recent determination under the Endangered Species Act that use of glyphosate as currently registered is likely to adversely affect both the terrestial and aquatic phases of one endangered amphibian species, the California red-legged frog (Summary document, pp. 5-6). We note that the Agency does not list a single study of the effects of glyphosate or its formulations on frogs or other amphibians (either aquatic or terrestial phase) in Tables 5 to 11 of the Ecological Risk background document. This is a serious flaw in the Agency's work plan that must be remedied as the registration review proceeds.

Second, the EPA should expand its ecological risk assessment to include glyphosate formulations that include non-POEA surfactants based on the Agency's finding that "only a few ecological effects studies have been conducted" with non-POEA formulations, and that there are "some non-POEA formulations that appear to be quite a bit more toxic than the technical material" (Ecological Risk background document, p. 19).

Third, the EPA should remove whatever internal impediments may exist to full consideration of high-quality research in the peer-reviewed literature regarding the ecological risks of glyphosate and its formulations. There is a surprising lack of references to any independent peer-reviewed scientific literature in the Ecological Risk background document, while the Agency specifically cites a Monsanto-prepared publication on the subject (Ecological Risk document, p. 6). The Agency states that it consults "open literature studies" (Ecological Risk, p. 17), but fails to present any evidence in the way of concrete references that it does so. EPA should not artificially limit its consultation of peer-reviewed scientific literature by overly restrictive screening procedures for "consistency," such as may be associated with acceptance into its ECOTOX database (Ibid). Excessive concern for consistency should not blind the Agency to high-quality data that has been generated by independent scientists and published in the peer-reviewed literature. Studies conducted by independent scientists and published in peer-reviewed journals are almost always of higher quality than registrant-conducted or commissioned studies.

Fourth, the EPA should make a priority of collecting full data on the surfactants contained in every glyphosate formulation, whether registered as a formulated product or not. EPA states: "For most formulations, we have no data. There is an uncertainty associated with formulations registered for aquatic uses and whether or not they contain POEA-type surfactants or other surfactants that are more toxic than technical glyphosate" (Ecological Risk document, p. 19). "There are many formulated products for glyphosate and the surfactants used in these products that must first be identified" (Ibid, p. 31). EPA should demand data on the specific surfactants in every glyphosate formulation that is employed in the field as a condition of FIFRA registration. In those cases where a company seeks registration of a glyphosate product that does not contain, but is invariably used with, surfactants (such as Rodeo), the formulations actually employed in the field including their corresponding surfactants should be subject to mandatory registration under FIFRA. EPA's admirable intent to collect data on the ecological risks posed by glyphosate formulations is seriously hampered by these data gaps.

Fifth, the Agency should not limit its assessment of the ecological toxicity of glyphosate formulations (with POEA or non-POEA surfactants) to those registered for direct application to water (as suggested in Ibid, p. 31). In Appendix A, aerial application is listed as permitted for fully 37 uses of glyphosate, including such large-scale agricultural applications as soybeans, corn, cotton, canola/rapeseed, wheat, alfalfa, agricultural fallow, non-food use crops and forestry. Glyphosate overspray of, and drift onto, wetlands and small bodies of water will be especially common with aerial applications over the vast acreages represented by such uses, and wetlands are the prime breeding ground for at-risk amphibian species such as frogs. Thus, EPA must expand its ecological effects testing requirements for glyphosate formulations to those registered for non-aquatic uses.

Sixth, the Agency should collect direct data on the ecological impacts of all glyphosate formulations, and not rely on separate analysis of surfactants' toxicity, either through collection of data from direct tests of the surfactants alone, or analysis of structure-activity relationships to extrapolate from the toxicity of known surfactants to those of similar structure (as suggested in Ecological Risks document, pp. 31-32). First, while some authors suggest that surfactants such as POEA are primarily responsible for ecological risks of glyphosate formulations (e.g. Relyea 2005a, cited above), others stress the importance of assessing formulations given the potential for additive or synergistic effects between active ingredient and surfactant(s).[26] When direct testing of formulations is not possible, toxicity testing of surfactants should be preferred to predictions from similarities in structure among surfactants.

CFS notes that EPA's review should also include further study of the toxicity of glyphosate formulations to freshwater aquatic plants, especially given the moderate to high toxicity found to duckweed and diatom, respectively (Ecological Risks, Table 6, p. 19; we note that EPA should fill in the "toxicity category" column for these two studies, with "Moderately toxic" (duckweed) and "Highly toxic" (freshwater diatom).

2) Glyphosate Use Adversely Affects Soil Biota, Linked to Plant Disease, Mineral Deficiencies and Reduced Yield

Transgenic glyphosate resistance facilitates the previously infeasible "over-the-top" application of glyphosate formulations to crops, raising novel food, feed, ecological and agronomic concerns. GR crops (e.g. corn, soybeans) are increasingly grown in rotation, meaning that each year, more prime cropland is sprayed more frequently with glyphosate, with increasing rates applied in many areas to control resistant weeds. While glyphosate is generally regarded as less toxic than many weed killers, a growing body of research suggests that continual use of this chemical may make RR plants more susceptible to disease and prone to mineral deficiencies than conventional crops, as well as reducing their yields. Some of these agronomic impacts are mediated through the impact of glyphosate on soil biota, an ecological effect that the EPA must consider in its ecological risk assessment.

[26] Diamond, G.L. & Durkin, P.R. (1997). "Effects of surfactants on the toxicity of glyphosate, with specific reference to RODEO," Syracuse Environmental Research Associates, submitted to USDA's APHIS, Feb. 6, 1997.

When Roundup is sprayed on RR crops, much of the herbicide ends up on the surface of the soil, where it is degraded by microorganisms. However, some is absorbed by the plant and distributed throughout its tissues. Small amounts of glyphosate are exuded from the roots of RR plants and spread throughout the surrounding soil.[27] This rhizosphere is home to diverse soil organisms, such as bacteria and fungi, that play critical roles in plant health and disease; and it is also where the roots absorb essential nutrients from the soil, often with the help of microorganisms.

The presence of glyphosate in the root zone of RR crops can have several effects. First, it promotes the growth of certain plant disease organisms that reside in the soil, such as *Fusarium* fungi.[28] Even non-RR crops planted in fields previously treated with glyphosate are more likely to be damaged by fungal diseases such as Fusarium head blight, as has been demonstrated with wheat and barley in Canada.[29] This research suggests that glyphosate has long-term effects that persist even after its use has been discontinued. Second, glyphosate can alter the community of soil microorganisms, interfering with the plant's absorption of important nutrients. For instance, glyphosate's toxicity to nitrogen-fixing bacteria in the soil can depress the absorption of nitrogen by RR soybeans under certain conditions, such as water deficiency, and thereby reduce yield.[30] Glyphosate-treated GR soybeans also have lower levels of manganese-reducing microorganisms in the rhizosphere,[31] inhibiting uptake of this essential nutrient and resulting in lower leaf levels of manganese.[32] Glyphosate treatment of GR sunflower reduces uptake and transport of both manganese and iron.[33] Glyphosate absorbed into GR crop plant tissues may also bind minerals and make them unavailable to the plant.[34] Finally, studies simulating low level glyphosate spray drift to non-transgenic soybean cultivars have demonstrated reduced leaf concentrations of calcium, manganese and magnesium, as well as reduced soybean seed concentrations of calcium, magnesium, iron and manganese.[35] Glyphosate treatment can foster increased disease

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[27] Motavalli, P.P. et al. (2004). "Impact of genetically modified crops and their management on soil microbially mediated plant nutrient transformations," *J. Environ. Qual.* 33:816-824; Kremer, R.J. et al. (2005). "Glyphosate affects soybean root exudation and rhizosphere microorganisms," *International J. Analytical Environ. Chem.* 85:1165-1174; Neumann, G. et al. (2006). "Relevance of glyphosate transfer to non-target plants via the rhizosphere," *Journal of Plant Diseases and Protection* 20:963-969.
[28] Kremer, R.J & Means, N.E. (2009). "Glyphosate and glyphosate-resistant crop interactions with rhizosphere microorganisms," *European Journal of Agronomy,* doi:10.1016/j.eja.2009.06.004; Kremer et al (2005), *op. cit.*
[29] Fernandez, J.R. et al (2009). "Glyphosate associations with cereal diseases caused by *Fusarium* spp. in the Canadian Prairies," *Eur. J. Agron.*, doi:10.1016/j.eja.2009.07.003; Fernandez, M.R., F. Selles, D. Gehl, R. M. DePauw and R.P. Zentner (2005). "Crop production factors associated with Fusarium Head Blight in spring wheat in Eastern Saskatchewan," *Crop Science* 45:1908-1916. http://crop.scijournals.org/cgi/content/abstract/45/5/1908.
[30] King, A.C., L.C. Purcell and E.D. Vories (2001). "Plant growth and nitrogenase activity of glyphosate-tolerant soybean in response to foliar glyphosate applications," *Agronomy Journal* 93:179-186.
[31] Kremer et al (2009), op. cit.
[32] Gordon, B. (2007). "Manganese nutrition of glyphosate-resistant and conventional soybeans," *Better Crops*, Vol. 91, No. 4: 12-13.
[33] Eker, S., Ozturk, L., Yazici, A., Erenoglu, B., Roemheld, V., Cakmak, I. (2006). "Foliar applied glyphosate substantially reduced uptake and transport of iron and manganese in sunflower (*Helianthus annuus L.*) plants. *J. Agric. Food Chem.* 54: 10019–10025.
[34] Bernards, M.L. et al (2005). "Glyphosate interaction with manganese in tank mixtures and its effect on glyphosate absorption and translocation," *Weed Science* 53: 787-794.
[35] Cakmak, I, Yazici, A., Tutus, U. and Ozturk, L. (2009). "Glyphosate reduced seed and leaf concentrations of calcium, manganese, magnesium and iron in non-glyphosate resistant soybean," *Eur. J. Agron.* Doi:10.1016/j.eja.2009.07.001.

susceptibility through fostering the growth of disease microorganisms, through inhibiting the production of plant defense compounds, and through reduced uptake of minerals essential to plant health and disease resistance.[36]

No ecological risk assessment would be complete without thorough data collection and analysis of these intertwined issues of glyphosate's impact on soil microbiota, nutrient deficiences and plant disease. These are not merely agronomic issues, but rather ecological issues involving soil biota that have important implications for American agriculture, particularly in view of the 150+ million plus acres planted to glyphosate-resistant crops and the roughly 200 million lbs. of glyphosate applied agriculturally in the U.S. each year.

IV. Assessment of Human Health Impacts of Glyphosate and its Formulations

CFS endorses the excellent discussion of the adverse impacts of glyphosate and its formulations on human health in comments submitted to this docket by Beyond Pesticides and Pesticide Action Network North America.

We would add the following additional comments. As with the ecological risk assessment, EPA states that it has "conducted an open search to look for new literature relevant to the human health risk assessment" (Human Health Scoping document, p. 3). Yet there is practically no reference in the scoping document to the many peer-reviewed studies suggesting harm from glyphosate exposure, especially occupational exposure. In the case of cancer, EPA's basis for classing glyphosate as a "Group E" chemical (evidence for non-carcinogenicity for humans) is studies in mice and rats. Case-controlled studies suggesting increased incidence of non-Hodgkin's lymphoma and hairy-cell leukemia in Roundup applicators go completely unmentioned.[37] EPA states that it has selected no endpoints for dermal or inhalational occupational exposure (Human Health Scoping document, p. 12), yet dermal, ocular and upper respiratory complaints figure prominently (2nd, 3rd and 4th most frequently reported categories) in the IDS database. Overall, the IDS database contains "a moderately large number of case reports" (Human Health Scoping document, p. 33), many of them considered possibly or probably related to glyphosate exposure. EPA should carefully and independently examine other such incidents in the TESS, NIOSH SENSOR and California databases, and search for correlations among them and its IDS database.

EPA should rescind its 2006 decision to waive the Food Quality Protection Act's stipulation of the 10x safety factor in view of the growing evidence that glyphosate and its formulations

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[36] Johal, G.S. & Huber, D.M. (2009). "Glyphosate effects on diseases of plants," *Eur. J. Agron.*, doi:10.1016/j.eja.2009.04.004; Benbrook, C. (2001). "Troubled Times Amid Commercial Success for Roundup Ready Soybeans: Glyphosate Efficacy is Slipping and Unstable Transgene Expression Erodes Plant Defenses and Yields," AgBioTech InfoNet Technical Paper No. 4, May 2001.

[37] Hardell, L., & Eriksson, M. (1999). "A Case-Controlled Study of Non-Hodgkin's Lymphoma and Exposure to Pesticides," *Cancer*, 85(6), 1353–1360; Hardell L, Eriksson M, & Nordstrom M. (2002). "Exposure to pesticides as risk factor for non-Hodgkin's lymphoma and hairy cell leukemia: pooled analysis of two Swedish case-control studies," *Leuk Lymphoma*, 43(5), 1043-1049; De Roos, et al. (2003). "Integrative assessment of multiple pesticides as risk factors for non-Hodgkin's lymphoma among men," *Occup Environ Med*, 60(9).

adversely affect embryonic, placental and umbilical cord cells.[38] This decision should also be revisited in light of the lack of chronic and subchronic neurotoxicity studies on glyphosate and its formulations, and the fact that neurological symptoms are the most frequently reported category of effects reported in EPA's IDS database (Human Health scoping document, Table 1, pp. 13-14). Impacts of glyphosate and its formulations on steroidogenesis have also been identified.[39]

EPA must correct several faulty tolerance listings in its Table 6 (Attachment 4). The Agency has apparently been raising glyphosate tolerances for various crops so frequently that its listing in Table 6 is already outdated. CFS has identified the following errors. The listing for Cotton, gin byproducts, is 210 ppm, not 175 ppm; Grain, aspirated fractions is 310 ppm, not 100 ppm; Poultry, meat is 4.0 ppm, not 0.1 ppm; and Soybean, hulls is 120 ppm, not 100 ppm.

In general, we note that the in part vastly increased tolerances since reregistration in 1993 (most to facilitate the introduction of glyphosate-resistant crops) have already resulted in substantially increased glyphosate exposure to the general population from increased glyphosate residues on crops and in meat products and byproducts.

V. Conclusion

CFS urges EPA to conduct a thorough and careful analysis of glyphosate's many adverse impacts on the environment and human health as outlined above. The unprecedented level of usage of this pesticide – far greater than any pesticide in the history of agriculture – demands an especially strict analysis.

Sincerely,

Bill Freese, Science Policy Analyst
Center for Food Safety

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[38] Benachour, N. & Seralini, G.-E. (2008). "Glyphosate formulation induce apoptosis and necrosis in human umbilical, embryonic and placental cells," *Chemica Research in Toxicology* 22(1): 97-105; Richard, S. et al (2005). "Differential effects of glyphosate and Roundup on human placental cells and aromatase," *Environmental Health Perspective* 113(6): 716-720.

[39] Walsh, O.P. et al (2000). "Roundup inhibits steroidogenesis by disrupting steroidogenic actue regulatory (StAR) protein expression," *Environmental Health Perspectives* 108: 769-776.

Appendix 1

Herbicide-Resistant Crops and Weeds

(Excerpted from CFS comments to USDA APHIS,
Docket No. APHIS 2008-0023,
June 29, 2009)

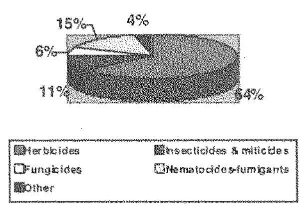
In past comments to the USDA on this rulemaking as well as on individual deregulation decisions, CFS has presented detailed arguments and evidence demonstrating that the unregulated use of genetically engineered, herbicide-tolerant (HT) crop systems – defined as an HT crop and use of its associated herbicide(s) – can have substantial negative impacts on U.S. agriculture, the environment and public health. These negative impacts include accelerated evolution of herbicide-resistant (HR) weeds; greater use of toxic herbicides to control HR weeds, and associated harm to the environment and public health; reduced yields as resistant weeds compete with crop plants for limited resources; increased soil erosion from greater use of mechanical tillage to control resistant weeds; increased costs to growers from herbicide-resistant weed control measures; and adverse health impacts on farmers from increased use of toxic herbicides to control resistant weeds. CFS has also urged USDA to exercize its noxious weed authority under the Plant Protection Act to mitigate these impacts, and make corresponding provisions in the proposed rule to this end. Below, we present new information and analysis to further support the need for regulation in this area. In brief:

1) The costs of (resistant) weeds to U.S. agriculture
   a) The pesticide treadmill
   b) Overview of herbicide use and herbicide-resistant weeds
   c) Herbicide-tolerant crop systems accelerate the pesticide treadmill
2) Acreage infested with glyphosate-resistant (GR) weeds continues to expand
   a) GR Palmer amaranth
   b) GR horseweed
   c) GR giant ragweed
3) Consequences of glyphosate-resistant weeds
4) The future of herbicide-tolerant crops: enhanced glyphosate-tolerance and tolerance to multiple herbicides
   a) Enhanced tolerance to glyphosate
   b) Multiple herbicide-tolerant crops
   c) Ongoing field tests involving herbicide-tolerant crops
5) Consequences of enhanced glyphosate and multiple herbicide-tolerant crop systems
6) Health consequences of herbcide-tolerant crop systems
7) Recommendations for APHIS regulation with respect to HT crop systems

1) The costs of (resistant) weeds to U.S. agriculture

Weeds compete with crops for limited supplies of nutrients and water, and can also shade crop plants, reducing yields. Weeds represent one of the biggest constraints on US crop production, costing an estimated $33 billion in lost crop productivity each year.[40] Since US food and fiber production is valued at over $115 billion annually,[41] weed competition reduces the production and value of US agricultural commodities by roughly 20% ($33 billion/($115+$33 billion). This huge loss in crop productivity attributable to weeds occurs despite the fact that US farmers apply over 400 million lbs. of herbicides annually,[42] at a cost of $7 billion.[43] While comprehensive lists are difficult to find, one source lists 287 herbicide active ingredients in use today in many more herbicide formulations (which often contain two or more active ingredients in various combinations).[44]

Figure 1: Agricultural Pesticide Use in the U.S. by Type: 2001



Herbicides comprise by far the largest category of pesticides, defined as any chemical used to kill plant, insect or disease-causing pests. In 2001, the last year for which the Environmental Protection Agency has published comprehensive data, weedkillers (herbicides) accounted for 433 million lbs. of the 675 million lbs. of chemical pesticides used in U.S. agriculture, nearly six-fold more than the insecticides that many associate with the term "pesticide." Source: "Pesticides Industry Sales and Usage: 2000 and 2001 Market Estimates," U.S. Environmental Protection Agency, 2004, Table 3.4. http://www.epa.gov/oppbead1/pestsales/01pestsales/market_estimates2001.pdf.

The pesticide treadmill

One reason farmers purchase and apply so many and such large quantities of herbicide is the growing problem of herbicide-resistant weeds. It is now generally acknowledged by agronomists that chemical-intensive pest (including weed) control methods can be counter-productive. This counter-intuitive notion – that greater reliance on pesticides exacerbates the problem it is meant to solve – is based primarily on two ecological insights: 1) Pesticides often kill not only pests, but natural predators of the pests that would otherwise help keep these pests in check (this applies mainly to insecticides/insects); and 2) Overreliance on particular pesticides generates enormous selection pressure that favors the survival of those rare individual pests that possess (genetically-endowed) natural resistance to the chemical(s). Over time, the resistant individuals gradually come to dominate the pest population. This applies to weeds as well as

[40] USDA ARS IWMU-1. Agricultural Research Service, Invasive Weed Management Unit, http://arsweeds.cropsci.illinois.edu/.

[41] USDA ARS Action Plan. "National Program 304: Crop Protection and Quarantine Action Plan 2008-2013," p. 1. http://www.ars.usda.gov/SP2UserFiles/Program/304/ActionPlan2008-2013/NP304ActionPlanwithCover2008-2013.pdf.

[42] $433 million lbs. in 2001, the latest year for which comprehensive data are available. See: EPA (2004). "Pesticides Industry Sales and Usage: 2000 and 2001 Market Estimates," U.S. Environmental Protection Agency, May 2004, Table 3.4. http://www.epa.gov/oppbead1/pestsales/01pestsales/market_estimates2001.pdf.

[43] USDA ARS IWMU-1, op. cit.

[44] Compiled by CFS from information available at http://www.weedscience.org/summary/ChemFamilySum.asp.

insects. In a related phenomenon known as "weed shifts," weed species with naturally greater tolerance to overused weedkillers gradually displace more susceptible species.

Resistant pests require higher doses to control, and/or the application of other pesticides still able to kill them. Together, these two phenomena have been dubbed the "pesticide treadmill." In the short term, as pests evolve higher levels of resistance to a particular pesticide, farmers can often apply more of it (run faster) to achieve the same killing effect. When resistance exceeds a certain threshold, however, it becomes more economical to switch over to a new pesticide. In the longer term, then, the pesticide treadmill is the sequential "burnout" of overused pesticides, followed by application of different and/or newer chemicals that in turn become ineffective.[45]

Seen in this light, the large number and quantity of herbicides used each year by American farmers is both a response to existing weed problems, as well as a causal factor leading to still greater reliance on herbicide use thanks to the evolution of resistance in weeds.[46]

USDA's Agricultural Research Service (ARS) estimates that up to 25% of annual US pest (weed and insect) control expenditures are attributable to pesticide resistance management.[47] This suggests that efforts to forestall and control herbicide-resistant weeds cost farmers roughly $1.7 billion each year (25% of $7 billion), and also helps explains why major components of USDA ARS's Action Plan: 2008-2013 (cited above) are devoted to ameliorating pesticide resistance, including herbicide-resistance in weeds.

Overview of herbicide use and herbicide-resistant weeds

Since World War II, weedkilling pesticides (herbicides) have become the major tool employed by U.S. farmers to combat weeds. From 1964 to 1997, overall herbicide use on major crops (corn, soybeans, wheat, cotton, potatoes, vegetables, fruits and berries) increased from 48.2 to 366.4 million lbs., a dramatic 7.6-fold increase. By 1997, weedkilling chemicals were applied to well over 90% of national acres planted to corn, soybeans and cotton.[48] In 2001, the U.S. accounted for a substantial 30% of all herbicides used in the world.[49]

This rapidly escalating use of herbicides beginning in the 1960s was followed by the emergence of herbicide-resistant weeds in the 1970s. Figure 2 below shows how rapidly herbicide-resistant

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[45] This simplified description glosses over nuances. For instance, those herbicide resistance mechanisms that endow weeds with high levels of resistance lead more quickly to burnout and switching to new herbicides (e.g. weed resistance to ALS inhibitor herbicides). In other cases (glyphosate resistance), increasing the dosage is a more feasible response, at least for a time. In many cases, both strategies are applied at once – increased dosage of the herbicide to which weeds have developed moderate resistance, together with application of other herbicides.

[46] One complicating factor is the historical trend towards development and use of more potent pesticides (i.e. effective at lower doses). When lower-dose pesticides replace higher-dose ones, overall pesticide use may well decline, even though the adverse impacts of pesticide use (resistance development, toxicity to the environment and/or human health) may not be reduced, and may even be exacerbated.

[47] USDA ARS Action Plan-App. II. "National Program 304: Crop Protection and Quarantine Action Plan 2008-2013," Appendix II, p. 2. http://www.ars.usda.gov/SP2UserFiles/Program/304/ActionPlan2008-2013/NP304CropProtectionandQuarantineApendixII.pdf.

[48] USDA ERS (2003). "Agricultural Resources and Environmental Indicators, 2003," USDA Economic Research Service, Chapter 4.3: Pest Management Practices, Tables 4.3.1 & 4.3.2. http://www.ers.usda.gov/publications/arei/ah722/arei4_3/AREI4_3pestmgt.pdf.

[49] EPA (2004), op. cit., Table 3.1, Figure 3.1.

biotypes have emerged. As of June 26, 2009, 330 resistant biotypes of 189 different weed species have been documented infesting over 300,000 fields in the world.[50] Just as the U.S. is the world's leader in herbicide use, so we have by far the most herbicide-resistant weeds, by several measures. The U.S. harbors 125 resistant biotypes of 68 different weed species that are documented in up to 213,000 fields covering up to 18 million acres.[51] The problem may well be worse, since these figures include only documented instances of resistant weeds collected in a passive reporting system. As discussed further below, weed scientists have reported many resistant weeds that have not been recorded on the WSSC-HRAC website cited above.

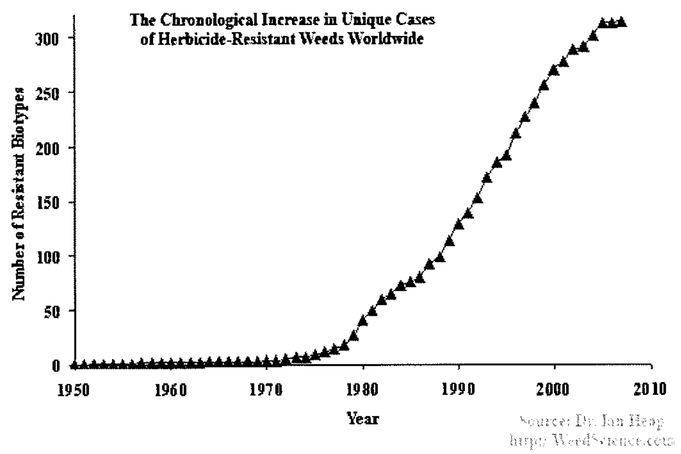

Figure 2: Source: "International Survey of Herbicide-Resistant Weeds," Weed Science Society of America and Herbicide-Resistance Action Committee. See link to "By Year 2007" chart at http://www.weedscience.org/In.asp. This chart has apparently not been updated since 2007.

The first major wave of herbicide resistant weeds in the U.S. that began in the 1970s involves 23 species of weeds resistant to atrazine and related herbicides of the photosystem II inhibitor class, which have been reported to infest up to 1.9 million acres of cropland in the U.S. The second

[50] See WSSA-HRAC (2009). "International Survey of Herbicide-Resistant Weeds," a project of the Weed Science Society of America (WSSA), funded and supported by the Herbicide Resistance Action Committee (HRAC), a group comprised of pesticide manufacturers, at: www.weedscience.com, last accessed June 26, 2009. As recently as February 2, 2009, the number of resistant biotypes was seven fewer (323), and resistant species two fewer (187), a crude measure of how quickly herbicide-resistant weeds are evolving (2/2/09 figures cited in CFS's prior comments on the proposed rule).

[51] WSSA-HRAC (2009), op. cit. For 125 resistant biotypes, see http://www.weedscience.org/summary/CountrySummary.asp, last accessed 6/26/09. Note that Australia is a distant second to the U.S. with 53 resistant biotypes, less than half the number found in the U.S. 213,000 fields and 18 million acres represent upper-bound estimates, as compiled by CFS from WSSA-HRAC website data in November 2007, except for glyphosate-resistant weeds, for which figures were updated on February 2, 2009.

major wave began in the 1980s, and involves 37 species of weeds resistant to ALS inhibitors, which have been documented infesting up to 152,000 sites covering 9.9 million acres. The third wave involves weeds resistant to glyphosate (see Figure 4).

Herbicide-tolerant crop systems accelerate the "pesticide treadmill"

Herbicide-tolerant (HT) crops are engineered to withstand direct application of a broad-spectrum herbicide to permit herbicide spraying to control weeds after the crop seedling has sprouted. This method of weed control is called "post-emergence" or "in-crop" herbicide application, as distinguished from "pre-emergence" application of herbicides before the crop seed has sprouted or "emerged."[52] HT crops create a strong incentive for farmers to make preferential, and in some cases exclusive, use of the HT-crop associated herbicide. Thus, HT crops must be assessed in conjunction with use of that herbicide, as "herbicide-tolerant crop systems." By encouraging overreliance on a particular herbicide, HT crop systems are uniquely suited to foster the rapid evolution of resistant weeds, just as overused antibiotics foster the evolution of bacteria resistant to them.

At present, the predominant HT crop system involves tolerance to the herbicide glyphosate. Monsanto's brand name formulations of this herbicide are known as Roundup, and the crops are dubbed Roundup Ready. It should be noted that many other manufacturers produce generic versions of glyphosate, which may also be used on Roundup Ready crops. Figure 5 displays acreage planted to the four major Roundup Ready crops in the U.S. over time, which by 2008 had reached 148.7 million acres.[53] As of 2008, Roundup Ready soybeans, cotton and corn comprised 92%, 93% and roughly 60% of all US acres planted to soybeans, cotton and corn, respectively.

The rapid adoption of Roundup Ready crops has been matched by a huge increase in glyphosate use. USDA NASS data show that overall glyphosate use on soybeans, corn and cotton increased by over 15-fold from 1994 (7.9 million lbs.) shortly before the introduction of Roundup Ready crops, to 2005 (119.1 million lbs.), the last year for which we have data for all three crops (Appendix 1). USDA NASS data also show that overall herbicide use has increased sharply on soybeans and cotton since 2001, and modestly on corn since 2002 (Figure 6).

The huge increase in acreage infested with glyphosate-resistant weeds portrayed in Figure 4 is directly attributable to the widespread adoption of Roundup Ready crop systems, and the excessive reliance they foster on glyphosate. For further background on the intertwined issues of

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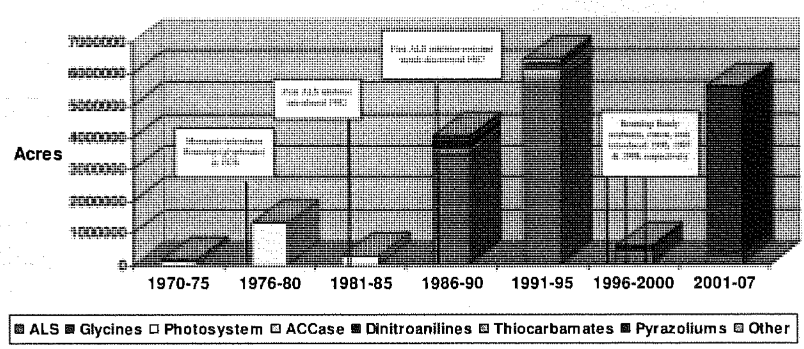
[52] Herbicides applied "pre-emergence" generally have "residual activity" of several days to weeks or longer, and are thus able to kill weeds that sprout subsequent to application.

[53] As APHIS has frequently noted, not all herbicide-tolerant crops are genetically engineered. Prior to development of transgenic techniques, companies used conventional breeding or mutagenic techniques to develop a number of herbicide-tolerant crops. However, it is important to note that the acreage planted to such varieties is a small fraction of that planted to genetically engineered (GE) HT crops. According to APHIS, conventionally-bred HT crops (mostly ALS inhibitor-resistant varieties: BASF's Clearfield corn, wheat, rice, canola and sunflower; DuPont-Pioneer's STS soybeans) were planted on roughly 6 million acres in 2007 (see APHIS (2008). "Finding of No Significant Impact on Petition for Nonregulated Status for Pioneer Soybean DP-356043-5," July 15, 2008, Response to Comments, p. 26. http://www.aphis.usda.gov/brs/aphisdocs2/06_27101p_com.pdf). This represents roughly 1/20th or 5% of the acreage planted to GE Roundup Ready soybeans, corn, cotton and canola in that year (128.2 million acres in the U.S. in 2007. See Figure 1 and Monsanto Biotechnology Trait Acreage: Fiscal Years 1996 to 2008, October 8, 2008. http://www.monsanto.com/pdf/investors/2008/q4_biotech_acres.pdf.)

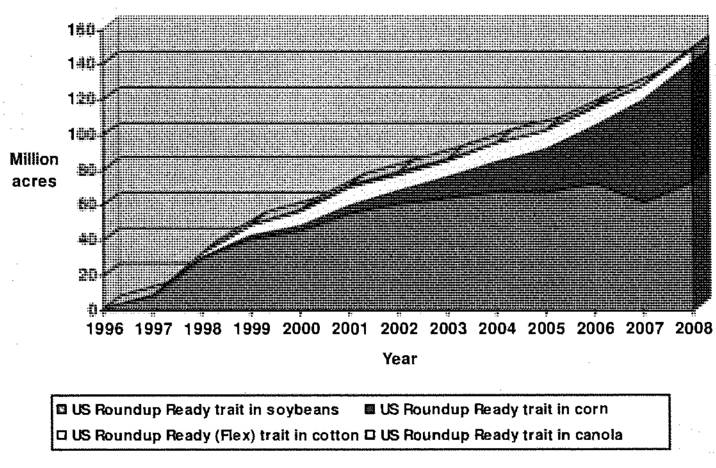
Roundup Ready crops, glyphosate use and glyphosate-resistant weeds, please refer to prior CFS comments to the USDA on the draft programmatic environmental impact statement, the

Figure 4: U.S. Crop Acreage Infested With Herbicide-Resistant Weeds by Class of Herbicide and Year Reported: 1970-2008



Compiled by CFS from WSSC-HRAC (2009), op. cit., last visited Feb. 3, 2009. Note that WSSC-HRAC report "acreage infested" figures in ranges due to the difficulty of determining the extent of a resistant weed population. The figures presented here represent aggregate upper-bound estimates. Note that glyphosate is the only member of the "glycines" class of herbicides.

Figure 5: U.S. Acreage Planted to Crops with Roundup Ready Trait: 1996 to 2008



Source: Monsanto Biotechnology Trait Acreage: Fiscal Years 1996 to 2008, October 8, 2008. http://www.monsanto.com/pdf/investors/2008/q4_biotech_acres.pdf.

proposed rule, and APHIS environmental assessements of various herbicide-tolerant crop deregulation petitions, which are incorporated here by reference. Below, we report recent findings on the continuing rapid expansion of glyphosate-resistant weeds.

2) Acreage Infested with Glyphosate-Resistant Weeds Continues to Expand

As Figure 4 illustrates, glyphosate-resistant (GR) weeds have evolved very rapidly in less than a decade. Today, WSSC-HRAC reports 41 documented GR biotypes of 9 different weed species in 19 states. Infestation with GR weeds continues to expand by both region of the country and overall acreage. For instance, weed scientists have recently reported GR weeds in South Dakota,[54] South Carolina and Alabama, though these reports have not (yet) been listed by WSSC-HRAC, bringing the total number of states with GR weeds up to at least 22. In addition, Canada recently reported its first suspected GR weed (giant ragweed).[55]

Except for isolated reports on the West Coast (California and Oregon), virtually all GR weeds have been linked to Roundup Ready cropping systems (soybeans, cotton and corn). Beginning in the year 2000 in Delaware, GR weeds first emerged in eastern and southern states, but were quickly found in states further west (e.g. Missouri, Kansas, Illinois). More recently, GR weeds have emerged in northern states (Minnesota, Michigan, South Dakota) as well as Canada.

More importantly, perhaps, is the dramatic increase in acreage infested with GR weeds. The reported extent of infestation in the U.S. has increased dramatically since just November of 2007, when GR populations of eight weed species were reported on no more than 3,251 sites covering up to 2.4 million acres. Today, GR weeds are reported on as many as 14,262 sites on up to 5.4 million acres.[56] In less than two years, then, the number of reported sites infested by GR weeds has increased by up to four-fold, while the maximum infested acreage has more than

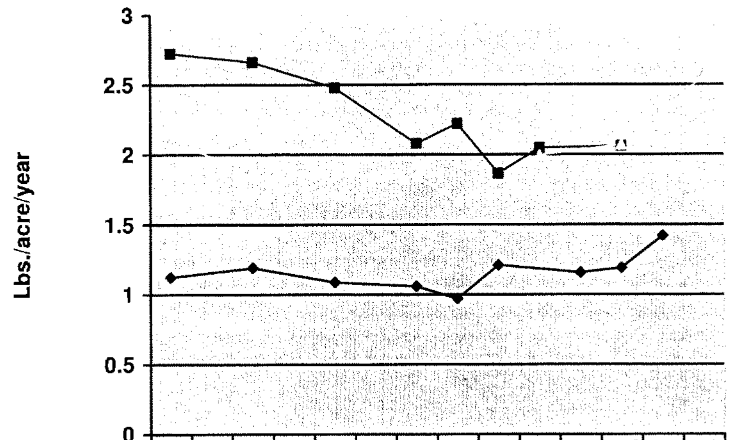
[54] ArgusLeader (2008). "Report: Roundup-resistant weeds pose challenge for SD soybean farmers," ArgusLeader.com, August 11, 2008.

[55] University of Guelph (2009). Guelph researchers find super ragweed," University of Guelph News Service, May 7, 2009. http://news.guelphmercury.com/News/article/478286

[56] We stress "reported" acreage because there can be lags between the times that resistant weeds emerge, are discovered, confirmed and reported. This increase in acreage infested with GR weeds is obscured by the WSSC-HRAC's puzzling practice of entering new reports of GR weeds under old dates. For instance, CFS's visits to the WSSC-HRAC website on November 21, 2007 and again on July 16, 2008 revealed just three reports of GR Palmer amaranth: 2005 in Georgia (up to 500 acres); 2006 in Tennessee (up to 500 acres) and 2006 in Arkansas (acreage unknown). When CFS checked the website again on Feb. 2, 2009, there was a ***new*** entry for GR Palmer amaranth in North Carolina (up to 1 million acres), but for some reason it was listed as a 2005 report. In addition, the pre-existing 2005 Georgia entry had been changed from up to 500 acres to up to 1 million acres. Likewise, there were no reports of GR horseweed in Illinois in our 2007 and 2008 searches; yet on 2/2/09, we found a ***2005*** entry for GR horseweed in Illinois on up to 1 million acres. There are several more examples of the same sort (new 2005 entries for GR giant ragweed in Minnesota and Arkansas that first turned up only in our 2009 search). Accurate tracking of resistant weed dynamics clearly requires an improved monitoring and reporting system, one preferably run by USDA and university weed scientists. We note that while WSSC is comprised of academic weed scientists, the Herbicide Resistance Action Committee (HRAC) is funded by biotechnology/agrichemical companies, which may well have an interest in downplaying the magnitude of the resistant weed problem.

doubled. And there is a strong trend for further increases in the future. Of the 41 reports of GR weed biotypes, 32 were reported as expanding in acreage, only two were not expanding, while information was not available for seven reports.

Figure 6: Herbicide Use on Major Field Crops in the U.S.: 1994 - 2007



	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Soybean	1.123		1.19		1.087		1.058	0.97	1.21		1.158	1.191	1.42	
Corn	2.724		2.662		2.48		2.08	2.223	1.865	2.049		2.061		
Cotton	2.082		1.893		1.854		1.842	1.664		1.996		2.071		2.56

Year

Soybean — Corn — Cotton

Notes: Herbicide use rates began rising in 2002 for soybeans and cotton, as GE herbicide-tolerant versions of these crops became prevalent (reaching 75% and 74% of overall crop acreage, respectively, in 2002). Herbicide use on corn rose slightly in 2003, but no trends apparent as of 2005, the last year for which we have data. Note that adoption of HT corn has lagged behind that of soybeans and cotton, rising from 11% to 26% of overall corn acreage from 2002 to 2005. Thus, more recent herbicide use data on corn is needed to determine whether increasing HT corn adoption since 2005 will have a similar effect as it has had for soybeans and cotton.
Sources: "Agricultural Chemical Usage: Field Crops Summary," USDA National Agricultural Statistics Service, for the respective years. See: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1560. The figures represent total herbicide use on the respective crop in the "Program States" included in USDA's survey, divided by the number of acres planted to that crop in the Program States. The Program States surveyed by USDA represent a high percentage of nationwide acreage planted to the crop (usually more than 80%, often more than 90%). The only assumption made here is that the amount of herbicides applied per acre covered by the survey is equal to that applied on acres not included in the survey. This is accepted practice for calculation of pesticide usage rates. For instance, compare Table 3.3.3 in Section 3.3: "Biotechnology and Agriculture," in: "Agricultural Resources and Environmental Indicators, 2006 Edition," USDA Economic Research Service, Economic Information Bulletin 16, July 2006, accessible from: http://www.ers.usda.gov/Publications/AREI/EIB16/. In this 2006 report, USDA for some unexplained reason plotted pesticide use on major field crops only up through 2001 or 2002, despite the availability of data for later years.

The nine species of weeds with documented GR biotypes in the U.S. as reported by WSSC-HRAC are: Palmer amaranth, common waterhemp, common ragweed, giant ragweed, horseweed, Italian ryegrass, rigid ryegrass, hairy fleabane and Johnsongrass.[57] Unfortunately, nearly all of the additional acreage infested by GR weeds over the past two years involves two of the most damaging to agriculture: Palmer amaranth and horseweed.

Case study of glyphosate-resistant Palmer amaranth

Glyphosate-resistant Palmer amaranth (a pigweed) has spread very rapidly in cotton, soybean, and to a lesser extent corn fields of the South. As of November 2007, WSSC-HRAC listed GR Palmer amaranth on just 4-7 sites comprising up to 1,000 acres in 3 states. Less than two years later, GR Palmer amaranth had been reported on over 500 sites in 7 states on as many as 2.1 million acres. It has thus expanded to infest orders of magnitude more sites and acreage.

For instance, GR Palmer amaranth was first reported in 2004 in just one county in Georgia. It quickly spread to 2 more counties in 2005, 7 additional counties in 2006, 10 more counties in 2007, and at least 9 further counties in 2008.[58] Upper-bound estimates of Georgia cotton and soybean acreage infested rose from a mere 500 acres in 2005 to 1 million acres in 2009.[59] In Tennessee, GR Palmer amaranth was first reported by WSSC-HRAC on two to five sites covering up to 500 acres in 2006. By 2008, it had spread to hundreds of fields in 10 Tennessee counties.[60] In North Carolina, GR Palmer amaranth was first reported less than a year ago infesting up to 1 million acres of corn, soybean and cotton fields.[61] GR Palmer amaranth was initially reported on just 1 site in Arkansas in 2006, but is now widespread,[62] by one account present in 18 Arkansas counties as well as two counties in Mississippi, with suspected cases in Louisiana as well.[63]

GR Palmer amaranth is also spreading to states not documented on WSSC-HRAC's website. For instance, it has been reported in 130,000 acres in South Carolina[64] and in Barbour County, Alabama in 2008; Auburn University weed scientist Mike Patterson predicts that GR Palmer amaranth will spread across southern Alabama fields in the coming years.[65]

GR Palmer amaranth has several of the features that APHIS cited as characteristic of federally listed noxious weeds in its proposed rule: it is aggressively invasive, as demonstrated by its

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[57] http://www.weedscience.org/Summary/UspeciesMOA.asp?lstMOAID=12&FmHRACGroup=Go (last visited June 28, 2009).

[58] Culpepper and Kichler (2009), "University of Georgia Programs for Controlling Glyphosate-Resistant Palmer Amaranth in 2009 Cotton," University of Georgia Cooperative Extension, April 2009.

[59] http://www.weedscience.org/Case/Case.asp?ResistID=5256.

[60] Robinson, E. (2008a). "Pollen big factor in resistant pigweed spread," Southeast Farm Press, April 28, 2009. http://southeastfarmpress.com/cotton/herbicide-resistance-0428/.

[61] http://www.weedscience.org/Case/Case.asp?ResistID=5360, a 2005 report that first appeared on WSSC-HRAC website in 2009, see footnote above for discussion.

[62] Bennett, D. (2008). "Resistant pigweed 'blowing up' in Mid-South," Delta Farm Press, July 30, 2008. http://deltafarmpress.com/cotton/resistant-pigweed-0730/.

[63] Robinson, E. (2008a), op. cit.

[64] Robinson, E. (2008b). "Designing the perfect weed - Palmer amaranth," Delta Farm Press, 12/24/08. http://deltafarmpress.com/cotton/palmer-amaranth-1226/

[65] Hollis, P.L. (2009). "Resistant pigweed control programs updated," Southeast Farm Press, May 19, 2009. http://southeastfarmpress.com/cotton/weed-resistance-0519/

explosive spread described above; it has significant negative impacts; and it is extremely difficult to control.[66] The mature weed can easily exceed six feet in height, and has an extremely sturdy stalk that can be from 6-8 inches wide at its base.[67] The weed is so tough that it can damage cotton pickers,[68] and GR Palmer amaranth infestations can lead to abandonment of cropland, as it did with 10,000 acres of cotton in Georgia in 2007.[69] Just two Palmer amaranth plants per 20 row feet of cotton can reduce yields by 23% or more.

Difficulties in controlling GR Palmer amaranth are attributable to its fecundity, the many modes of propagation, and the paucity of weed control options. As to its fecundity, a single female plant can produce up 450,000 seeds. GR Palmer amaranth seed can become lodged in harvesting equipment, which unless thoroughly cleaned, can lead to propagation of the resistant seed to other fields; farmers' use of custom harvesters poses similar propagation risk.[70] In Louisiana, where at present there are suspected GR Palmer amaranth but no documented glyphosate-resistant weeds, experts even worry that farmers buying used soybean harvesting equipment from areas infested with GR weeds will inadvertently import the problem to the state.[71] Scientists in Arkansas and Tennessee believe that GR Palmer amaranth seed is spread via flooding as well, having noted that river counties have the most widespread resistance problems.[72] However, long-distance pollen flow is probably the most significant mode of propagation. In one experiment, a substantial 20% of the seeds of glyphosate-susceptible female plants at a distance of 300 meters from a pollinating resistant male plant produced glyphosate-resistant progeny.[73]

The multiple modes of propagation, especially long-distance pollen flow, help account for the GR weed's extremely rapid march across southern states in the past two years. Another key factor is the enormous selection pressure for GR biotypes from overreliance on glyphosate with Roundup Ready cotton, soybean and corn crop systems, which are often grown in rotation.

Glyphosate-resistance in this extremely damaging weed makes it all the more expensive and difficult to control. The difficulty in controlling a weed is a major factor that must be considered in assessments of whether it merits designation as "noxious." One facet is the increasing level of resistance. In both Georgia and Tennessee, resistance levels as measured by dose of glyphosate required to control GR Palmer amaranth have been rising. Initially in Tennessee, some GR Palmer amaranth could survive 44 ounces of Roundup, requiring 88 ounces for control (88 ounces exceeds the label rate); in 2008, resistant weeds were found that required an astronomical

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[66] USDA APHIS (2008), Proposed Rule, October 9, 2008, FR 73: 60008-46, at 60013.

[67] Roberson, R. (2008). "Herbicide-resistant weed problems spreading," Southeast Farm Press, May 14, 2008.

[68] Minor, E. (2006). "Herbicide-resistant weed worries farmers," *Associated Press*, 12/18/06, available at http://www.enn.com/top_stories/article/5679 (last visited Sept. 9, 2007).

[69] Robinson, E. (2008b), op. cit.

[70] Culpepper, S. and J. Kichler (2009), op. cit.; Robinson, E. (2008a). "Pollen big factor in resistant pigweed spread," Southeast Farm Press, April 28, 2009. http://southeastfarmpress.com/cotton/herbicide-resistance-0428/.

[71] Bennett, D. (2009). "Lousiana: sugarcane and soybeans," Delta Farm Press, June 3, 2009. http://deltafarmpress.com/soybeans/sugarcane-soybeans-0603/.

[72] Bennett, D. (2008), op. cit. "Resistant pigweed 'blowing up' in Mid-South," Delta Farm Press, July 30, 2008. http://deltafarmpress.com/cotton/resistant-pigweed-0730/.

[73] Robinson, E. (2008a), op. cit.

152 ounces of glyphosate to kill. ***In some cases, Palmer amaranth actually exhibits higher levels of resistance to glyphosate than the Roundup Ready soybeans in the field.***[74]

Rising levels of glyphosate resistance means that control of the weed is more expensive. Increasing costs of weed control to farmers is a significant negative impact of a weed that also deserves consideration in assessments of its noxious qualities. Larry Steckel, weed scientist at the University of Tennessee, estimated in 2006 that on average, glyphosate-resistant Palmer amaranth would cost cotton growers in the South an extra $40 or more per acre to control.[75] This represents a substantial burden, as cotton farmers' average expenditure on ***all*** pesticides (insecticides and herbicides) was $61 per acre in 2005.[76] Another expense is the need for increasing use of manual labor to remove GR Palmer amaranth. In both Arkansas and Tennessee, the use of "chopping crews" to remove this weed is sharply increasing.[77] The expansion of GR Palmer amaranth from mere hundreds of acres (when these reports were first made) to as many as 2 million acres of cotton, soybean and corn fields just a few years later means that the cost of controlling it has likewise risen dramatically.

Another facet of assessing the difficulty of weed control is the availability of alternative control methods. In this case, there are few economical options for dealing with GR Palmer amaranth, in part because many populations of Palmer amaranth are already resistant to other herbicides. Weed scientist Alan York and Cotton, Inc.'s Bob Nichols note that many populations of Palmer amaranth are already resistant to members of a widely used class of alternative herbicides known as ALS inhibitors, and are concerned that increasing reliance on a third class of herbicides, PPO inhibitors, will drive weed resistance to them as well. In fact, some populations are already resistant to glyphosate as well as ALS inhibitors. Palmer amaranth with dual resistance to glyphosate and ALS inhibitors has been reported in both Mississippi by WSSC-HRAC[78] and by Alan York in North Carolina.[79]

> "'But we also have a lot of ALS resistance in Palmer amaranth and we can't depend too much on that chemistry. We're also putting a lot of pressure on PPO inhibitors like Reflex, Valor, Blazer, Flexstar, and others. We cannot afford to lose those chemistries,' [said York]...."
>
> While York and Nichols are concerned about glyphosate resistance, growers should keep in mind that resistance to ALS herbicides such as Classic and Harmony is common ***and the potential to select for resistance to PPO-inhibiting herbicides such as Reflex, Valor, and Cobra certainly exists.***
>
> 'When we hear the term herbicide resistance, we automatically think glyphosate,' York said. 'I don't want to belittle glyphosate resistance. We know how much we depend on glyphosate, and it is a serious matter. But resistance is not unique to glyphosate.'

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[74] Robinson, E. (2008a), op. cit., emphasis added.
[75] Laws, F. (2006). "Glyphosate-resistant weeds more burden to growers' pocketbooks," *Delta Farm Press*, November 27, 2006, http://deltafarmpress.com/news/061127-glyphosate-weeds/
[76] USDA ERS (2007b). Cost and return data for cotton production: 1997-2005. USDA Economic Research Service, last accessed January 12, 2007. http://www.ers.usda.gov/data/CostsandReturns/data/recent/Cott/R-USCott.xls.
[77] Bennett, D. (2008), op. cit.
[78] http://www.weedscience.org/Case/Case.asp?ResistID=5359.
[79] Roberson, R. (2008), op. cit.

Nichols describes the Palmer pigweed situation as a 'serious economic threat to weed management in cotton. ***We need a general resistance management plan for the PPOs. PPOs are between us and the ability to do economic weed control in cotton and soybeans.***'"[80]

APHIS has frequently rejected CFS's call for USDA to take regulatory action on herbicide-tolerant crop systems and their propensity to foster herbicide-resistant weed populations by noting that herbicide-resistant weeds are not unique to GE crops, and that other weed control options are available when weeds evolve resistance to glyphosate or other herbicides. The second point is rapidly being proven false in the case of GR Palmer amaranth. The first point is simply irrelevant. It is equivalent to rejecting the need to take action on global warming by reference to damaging climatic events that have occurred throughout human history, before the advent of anthropogenic climate change. The point is not to split hairs about cause, but to tackle the problem at hand using all available regulatory tools. It is interesting to note that the weed scientist and cotton expert quoted above do NOT regard the prior evolution of herbicide-resistant weeds that are unrelated to GE herbicide-resistant crops (i.e. those resistant to ALS inhibitors) as grounds for inaction on the glyphosate-resistant weed epidemic, as APHIS does. On the contrary, they assess the GR weed threat in a comprehensive and cumulative manner, against the backdrop of pre-existing weed resistance problems (resistance to ALS inhibitors) and prospectively for its impacts on the viability of the few remaining chemical weed control options (PPO inhibitors).

GR Palmer amaranth is one of several factors that together pose a serious threat to the continued viability of the cotton industry in the United States. Already in 2006, North Carolina State University weed scientist Alan York described GR Palmer amaranth as "...potentially the worse threat [to cotton] since the boll weevil."[81]

Other weed scientists agree. According to Larry Steckel, speaking of GR Palmer amaranth:

> "One of the biggest concerns with this is, quite frankly, **it could run us out of cotton**. In soybeans, at least we have some options. In cotton those aren't there — once pigweed is up, it's safe.
>
> "**That's my greatest fear: losing cotton.** Between commodity prices, plant bug numbers appearing to pick up and this resistant-Palmer amaranth explosion, cotton is an increasingly tough sell."[82]

Clearly, the explosive spread of GR Palmer amaranth due to the unregulated use of Roundup Ready crop systems and the grave threat it poses to the cotton industry illustrates the need for APHIS to develop a comprehensive regulatory program to deal with the serious threats to the "interests of agriculture" posed by herbicide-tolerant crop systems and the resistant weeds they foster.

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[80] Robinson, E. (2008b), op. cit.
[81] As quoted in Minor, E. (2006), op. cit.
[82] As quoted in: Bennett, D. (2008), op. cit., emphasis added.

Glyphosate-resistant horseweed

Glyphosate-resistant horseweed has also spread rapidly over the past two years. Since November 2007, it has been documented infesting up to 10,000 sites on as many as 1 million acres in Illinois,[83] the largest report since its discovery on over 2 million acres in 2001 in Tennessee.[84] An additional report of GR horseweed in Mississippi dated 2007 involves horseweed that is resistant to paraquat as well as glyphosate,[85] the first time WSSC-HRAC has documented multiple resistance to these two herbicides. Today, GR horseweed is the most widely dispersed GR weed, found in 16 states on up to 3.3 million acres.

GR horseweed is considered a "worst-case scenario" for glyphosate-tolerant crop systems because it is well adapted to no-tillage systems popular among GR crop growers, has a high level of fecundity (up to 200,000 seeds per plant), and its seeds disperse extremely long distances in the wind.[86] Left unchecked, horseweed can reduce cotton yields by 40-70%.[87] An Arkansas weed scientist estimated that Arkansas growers would have to spend as much as $9 million to combat glyphosate-resistant horseweed in 2004.[88] In 2005, Arkansas extension agent Mike Hamilton estimated that an uncontrolled outbreak of glyphosate-resistant horseweed in his state had the potential to cost Arkansas cotton and soybean producers nearly $500 million in losses, based on projected loss in yield of 50% in 900,000 acres of Arkansas cotton and a 25% yield loss in the over 3 million acres of Arkansas soybeans.[89] GR horseweed is even worse in Tennessee, reportedly infesting all cotton acres grown there. Larry Steckel reports that GR horseweed populations are becoming more dense in Tennessee; while 10 plants per square foot was considered heavy in 2004-2005, by 2006-07 bad infestations involved populations of from 20 to 25 plants per square foot.[90] In Tennessee, as well as Missouri, Arkansas, and Mississippi, GR horseweed is driving farmers to use mechanical tillage for control, reducing substantially the (cotton) acreage under conservation tillage.[91] This in turn can lead to increased soil erosion. As with Palmer amaranth, there are few good weed control options once a horseweed population has developed glyphosate resistance.[92]

Glyphosate-resistant giant ragweed

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[83] See http://www.weedscience.org/Case/Case.asp?ResistID=5276. As noted above, although this report is dated 2005, it was first listed by WSSC-HRAC in the past year.
[84] http://www.weedscience.org/Case/Case.asp?ResistID=5122.
[85] http://www.weedscience.org/Case/Case.asp?ResistID=5384.
[86] Owen, MDK (2008). "Weed species shifts in glyphosate-resistant crops," *Pest Management Science* 64: 377-387.
[87] Laws, F. (2006), op. cit.
[88] AP (2003). "Weed could cost farmers millions to fight," *Associated Press*, 6/4/03, http://www.biotech-info.net/millions_to_fight.html
[89] James, L. (2005). "Resistant weeds could be costly," Delta Farm Press, July 21, 2005. http://deltafarmpress.com/news/050721-resistant-weed/.
[90] Robinson, E. (2008c). "Weed control growing much more complex, new tools coming," Delta Farm Press, March 27, 2008.
[91] Steckel, L., S. Culpepper and K. Smith (2006). "The Impact of Glyphosate-Resistant Horseweed and Pigweed on Cotton Weed Management and Costs," Power Point presentation at Cotton Incorporated's "Crop Management Seminar," Memphis, 2006. http://www.cottoninc.com/CropManagementSeminar2006/SeminarProceedings/images/Steckle%20Larry.pdf; Laws, F. (2006), op. cit.
[92] Owen, MDK. (2008), op. cit.

Since just 2004, 6 reports of glyphosate-resistant giant ragweed have been reported in Ohio, Arkansas, Indiana, Minnesota, Kansas and Tennessee. Purdue University extension agents first confirmed a single population of glyphosate-resistant giant ragweed in Indiana in December of 2006;[93] just a year and half later, they announced GR giant ragweed in 14 counties in Indiana, and noted that some are also dual-resistant to ALS inhibitors as well.[94] Ohio State University researchers have reported giant ragweed with relatively high levels of resistance to both PPO and ALS inhibitor herbicides in three counties, and populations with lower levels of dual resistance in four other counties. They warn that although these weeds can be managed with glyphosate, "continuous use of this practice is likely to result in resistance to glyphosate as well."[95]

Giant ragweed is considered the most competitive broadleaf weed in Indiana soybean production. It can grow up to 15 feet tall, and 3 to 4 giant ragweed plants per square yard can reduce crop yields by as much as 70%.

<u>**3) Consequences of glyphosate-resistant weeds**</u>

Increased number and rate of glyphosate applications. Resistant/tolerant weeds can often still be killed by increased application rates, and farmers are in fact applying substantially more glyphosate to this end. For instance, USDA NASS data show that the average number of glyphosate applications per year on soybeans and cotton has risen from 1.0 for both soybeans in 1995 and for cotton in 1996 (the year before the introductions of RR soy and RR corn in 1996 and 1997, respectively) to 1.7 for soybeans (2006) and to 2.4 for cotton (2007). The average amount applied per application has also risen by 25% over this period for both crops. Thus, glyphosate use per acre per year on glyphosate-treated acres has more than doubled for soybeans (0.61 to 1.32 lbs) and nearly tripled for cotton (0.66 to 1.87 lbs.) over these time periods.

Health risks: Glyphosate is generally considered less toxic than many herbicides, yet certain Roundup formulations (especially those containing the adjuvant polyethoxylated tallowamine or POEA) have been found to pose greater risks to human health and the environment than glyphosate alone. Roundup use has been associated with increased risk of non-Hodgkin's lymphoma and hairy cell leukemia in pesticide applicators,[96] and increased risk of neurobehavioral disorders in children of Roundup applicators.[97] Roundup/glyphosate has been shown to inhibit steroidogenesis.[98] Both Roundup and glyphosate have been found to inhibit the aromatase enzyme involved in estrogen production, though Roundup was more potent.[99]

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[93] Johnson, B and Loux, M. (2006). "Glyphosate-resistant giant ragweed confirmed in Indiana, Ohio," Purdue University press release, 12/21/06.

[94] Johnson, B and G Nice (2008). "Lots of weedy soybean fields," Purdue Extension Weed Science, July 2008.

[95] Loux, M and J Stachler (2008). "Giant ragweed with resistance to PPO and ALS inhibiting herbicides," Crop Observation and Recommendation Network Newsletter 2008-11, 4/29 to 5/6/08.

[96] Hardell et al (2002). Exposure to pesticides as risk factor for non-Hodgkin's lymphoma and hairy cell leukemia: pooled analysis of two Swedish case-control studies," *Leuk. Lymphoma*, 43(5):1043-9.

[97] Garry et al (2002). "Birth Defects, Season of Conception, and Sex of Children Born to Pesticide Applicators Living in the Red River Valley of Minnesota, USA," *Environmental Health Perspectives*, 110, Suppl. 3, 441-449.

[98] Walsh et al (2000). "Roundup inhibits steroidogenesis by disrupting steroidogenic acute regulatory (StAR) protein expression," *Environmental Health Perspectives*, 108(8):769-76.

[99] Richard et al (2005). "Differential Effects of Glyphosate and Roundup on Human Placental Cells and Aromatase," *Environmental Health Perspectives*, 113: 716-720; for a comprehensive review of the adverse human

Glyphosate formulations have also been shown to cause cell death and necrosis in various human cell cultures at fairly low levels.[100]

Increased risks to amphibians: Certain formulations of Roundup have been found to be highly toxic to amphibians at field-relevant usage rates.[101]

Constant or rising use of other herbicides: Increasingly, weed scientists and Monsanto are advising farmers to employ non-glyphosate herbicides (preemergence, residual herbicides; tank mixes) to control and forestall the further spread of glyphosate-resistant weeds. For instance, paraquat and 2,4-D are recommended in addition to glyphosate to control GR horseweed and pigweed.[102]

4) The future of herbicide-tolerant crops: enhanced glyphosate-tolerance and tolerance to multiple herbicides

Thus far, we have discussed the threats posed by several glyphosate-resistant weeds, particularly GR Palmer amaranth. We have focused on GR weeds because their rise is intimately linked to the predominant HT cropping system. However, as discussed further below, biotech companies plan to introduce many more herbicide-tolerant crops, which represent their most active area of research and development. These crops are being developed in direct response to the glyphosate-resistant weed epidemic. In the programmatic EIS and proposed rule, APHIS keyed the revision of its regulation of GE crops to the in part different new risks presented by newer developments in agricultural biotechnology, such as pharmaceutical-producing crops and fitness-related traits. However, APHIS completely ignored significant new developments and associated risks in the HT crop arena, as evidenced by its extremely cursory and deficient treatment of the subject in the draft Programmatic Environmental Impact Statement (draft pEIS). In that document, APHIS provided absolutely no prospective assessment of this vigorous field of agricultural biotechnology research and development. In fact, the discussion did not even begin to address the existing problem of glyphosate-resistant weeds spawned by the currently dominant glyphosate-tolerant crop systems, failing to name, much less discuss, even one GR weed in the United States.[103] This serious deficiency must be remedied in the final rule. Below, we first

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and environmental impacts of glyphosate, see: FoE UK (2001). "Health and Environmental Impacts of Glyphosate," Friends of the Earth UK, July 2001. http://www.foe.co.uk/resource/reports/impacts_glyphosate.pdf.

[100] Benachour, N. & Seralini, G.E. (2009). "Glyphosate formulation induce apoptosis and necrosis in human umbilical, embryonic, and placental cells," *Chem. Res. Toxicol.* 22(1):97-105

[101] Relyea, R.A. (2005). "The lethal impact of Roundup on aquatic and terrestial amphibians," *Ecological Applications* 15(4): 1118-1124; Relyea, R.A., N.M Schoeppner & J.T. Hoverman (2005). "Pesticides and amphibians: the importance of community context," *Ecological Applications* 15(4): 1125-1134.

[102] Laws, F. (2006). "Glyphosate-resistant weeds more burden to growers' pocketbooks," *Delta Farm Press*, November 27, 2006, http://deltafarmpress.com/news/061127-glyphosate-weeds/. For an overview of recommendations by weed scientists and Monsanto for controlling and/or forestalling GR weeds, see: FoEI-CFS (2008). "Who Benefits from GM Crops? The Rise in Pesticide Use," Friends of the Earth International-Center for Food Safety, January 2008, Section 2.3. http://www.centerforfoodsafety.org/pubs/FoE%20I%20Who%20Benefits%202008%20-%20Exec%20Sum%20FINAL.pdf.

[103] USDA APHIS (2007). Introduction of Genetically Engineered Organisms, Draft Programmatic Environmental Impact Statement, July 2007. See pp. 119-121 for the thoroughly inadequate discussion of herbicide-tolerant crops, which fails to even name a single glyphosate-resistant weed population in the US.

describe some of these new developments, followed by an assessment of the potential risks they pose. Two themes emerge: crops with enhanced levels of glyphosate-tolerance, and crops with tolerance to multiple herbicides.

First, nearly half (6 of 14) of GM crops pending deregulation with USDA are herbicide-tolerant (see Table 1). This represents the near-term pipeline, and assuming they are approved, the near-term future of agricultural biotechnology.

Table 1: The 14 GM Crops Pending Deregulation (Commercial Approval) by USDA
(as of February 5, 2009)

Trait	No.	Notes
Tolerate 1 herbicide	5	Glyphosate-tolerant alfalfa and creeping bentgrass (Monsanto) Glyphosate-tolerant (1) and glufosinate-tolerant/insect-resistant (1) cotton (Bayer) ALS inhibitor-tolerant soybeans (BASF)
Tolerates 2 herbicides	1	Dual herbicide-tolerant corn tolerates glyphosate and imidazolinones (a class of ALS inhibitor herbicides) (DuPont-Pioneer)
Insect-resistant alone	2	Corn and cotton (Syngenta)
Virus-resistant	1	New version of old papaya trait (University of Florida)
Enzyme added	1	Corn w/ alpha-amylase enzyme derived from deep sea microorganisms for processing into ethanol. First GE industrial crop. Novel enzyme in corn has characteristics of food allergens, leading top U.S. food allergists to call for more careful evaluation of potential allergy-causing potential of this corn variety. South Africa has refused import clearance based in part on inadequate analysis of potential health impacts from consumption of this corn (Syngenta)
Sterile pollen, fertility altered	2	Corn with sterile pollen (DuPont-Pioneer); freeze-tolerant eucalyptus tree with altered fertility (ArborGen)
Oil alteration	1	High oleic acid soy for processing (DuPont-Pioneer)
Color alteration	1	Carnation (Florigene)

Source: USDA Petitions for Nonregulated Status Pending, February 5, 2009, at: http://www.aphis.usda.gov/brs/not_reg.html (last accessed February 9, 2009).

Enhanced resistance to glyphosate

There has been a trend to increase the level of glyphosate-tolerance in newer glyphosate-tolerant crops. This was first seen with the 2006 introduction of Monsanto's Roundup Ready Flex cotton, the successor to its original RR cotton.[104] The label for Roundup Ready Flex cotton recommends 1.5 times the application rate of that applied to original RR cotton (32 ounces/acre

[104] Bennett, D. (2005). "A look at Roundup Ready Flex cotton," *Delta Farm Press*, 2/24/05, http://deltafarmpress.com/news/050224-roundup-flex/.

for Flex vs. 22 ounces/acre for original RR cotton.[105] With original RR cotton, the CP4 EPSPS enzyme (RR trait) was not expressed in reproductive tissues, limiting the "application window" to the immature plant. RR Flex expresses the enzyme in reproductive tissues, permitting application of glyphosate to mature plants as well. With RR Flex cotton, farmers are enabled to wait until weeds become larger before applying glyphosate; larger weeds require higher application rates to kill, and are also more likely to flower and set seed. Any resistant individuals that are allowed to flower and set seed can then spread the resistance trait in two ways: 1) Spatially, through cross-pollination with susceptible weeds; and 2) Over time, by leaving weed seeds bearing the resistance trait in the seed bank to sprout in subsequent seasons. Introduction of RR Flex cotton may well have contributed to the steep (24%) increase in herbicide use on cotton from 2005 to 2007 (see Figure 6).

DuPont-Pioneer's Optimum GAT corn (pending approval by USDA)[106] contains a new mechanism of glyphosate resistance, different than Roundup Ready. GAT stands for glyphosate acetyltransferase, which inactivates glyphosate by adding an acetyl group to it. One report by DuPont scientists suggests that Optimum GAT corn may survive six times the normal dose of glyphosate "with no adverse symptoms."[107] This would permit higher doses of glyphosate application.

In a patent,[108] DuPont-Pioneer proposes to "stack" GAT with one or both of Monsanto's mechanisms of glyphosate-resistance (CP4 EPSPS and GOX [glyphosate oxidoreductase]) in order to enhance tolerance to glyphosate still more and so enable applications of higher rates to kill increasingly resistant weeds.

Likewise, a biotech startup company in North Carolina, Athenix, is also developing a bacterial gene to confer enhanced glyphosate tolerance in crops.[109]

Finally, APHIS recently deregulated Bayer CropScience's GlyTol cotton, which incorporates still another new mechanism of glyphosate resistance.[110] Bayer informed APHIS that the company did not request a glyphosate label change with EPA and is using the current label

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[105] See Monsanto 2008 Technology Use Guide, pdf pages 31 and 34.
[106] USDA Petitions for Nonregulated Status and any (draft) environmental assessments (EA) by USDA's APHIS are listed at http://www.aphis.usda.gov/brs/not_reg.html. DuPont-Pioneer's corn is petition 07-152-01p. For fuller discussion of this dual-HR corn, see also: "Comments to USDA APHIS on Environmental Assessment for the Determination of Nonregulated Status for Pioneer Hi-Bred International, Inc. Herbicide Tolerant 98140 Corn," Center for Food Safety, February 6, 2009, http://www.centerforfoodsafety.org/pubs/CFS%20comments%20on%20Pioneer%20HT%2098140%20corn%20EA_final_2_6_09-FINAL.pdf.
[107] Castle et al (2004). "Discovery and directed evolution of a glyphosate tolerance gene," *Science* 304: 1151-54. For discussion, see CFS comments cited in last footnote.
[108] "Novel Glyphosate-N-Acetyltransferase (GAT) Genes," U.S. Patent 2005/0246798, issued Nov. 3, 2005, assigned to: Verdia, Inc. and Pioneer Hi-Bred International.
[109] Service, R.F. (2008). "A growing threat down on the farm," *Science* 316: 1114-1117.
[110] See USDA website listed above, petition 06-332-01p. For CFS comments, see: http://www.centerforfoodsafety.org/pubs/Bayer%20GlyTol%20Cotton%20Comments%20-%20CFS%20FINAL%208-18-08.pdf.

application rate of glyphosate on their GHB614 product.[111] However, Cheminova, Inc., a manufacturer of glyphosate and other pesticides based in Denmark, has applied for and obtained from EPA a tolerance increase for residues of glyphosate on cotton gin byproducts (from 175 to 210 ppm) that was specifically linked to introduction of GlyTol cotton.

> "Cheminova, Inc. has requested a Section 3 registration under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) for application glyphosate to glyphosate-tolerant cotton including Bayer GHB614 cotton (GlyTol cotton), a genetically modified cotton being commercialized by Bayer Crop Science. As a result, the petitioner has requested that the current tolerance for cotton, gin byproducts be increased to 210 ppm."[112]

In this same FR notice, EPA also refers to an Agency review entitled "Glyphosate Label Amendment to Permit Application of Glyphosate to Bayer's Glyphosate-Tolerant Cotton GHB614."[113] Thus, it appears that introduction of Bayer's GlyTol cotton requires both a tolerance increase and a glyphosate label amendment, suggesting that higher rates of glyphosate will be applied to this glyphosate-tolerant cotton; otherwise, there would seem to be little reason to seek and obtain a tolerance increase. The preexisting glyphosate tolerance for cotton gin byproducts was 175 ppm, which itself represented an increase from the corresponding tolerance prevailing in 2000 of 100 pm.

Multiple herbicide-resistant crops
Agrichemical-biotech firms are also devoting substantial research and development efforts to herbicide-resistant crops that withstand two or more herbicides rather than just one.

DuPont-Pioneer has developed Optimum GAT soybeans[114] and corn, both of which combine enhanced GAT resistance to glyphosate with resistance to ALS-inhibitor herbicides. Optimum GAT soybeans were granted commercial approval last year; as noted above, Optimum GAT corn is pending approval by USDA. Optimum GAT crops combine resistance to the two classes of herbicides (glycines [of which glyphosate is the only member] and ALS inhibitors) to which weeds have developed the most extensive resistance (by acreage) in the United States (see Figure 4 above). BASF is also developing ALS inhibitor-resistant soybeans, which are currently pending deregulation by USDA as transformation event BPS-CV127-9.[115] These soybeans may well be stacked with resistance to glyphosate in the context of the Monsanto-BASF joint-licensing agreement (discussed below).

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[111] APHIS (2009). "Determination of Non-regulated Status for Glyphosate-Tolerant (GlyTol) Cotton, Gossypoium hirsutum, event GHB614: Final Environmental Assessment, April 15, 2009, Response to Comments section, p. 24.
[112] EPA (2009). "Glyphosate; Pesticide Tolerances," FR Vol. 24, No. 120, June 24, 2009, pp. 29963-29996.
[113] Id., p. 29964.
[114] See USDA website listed above, petition 06-271-01p. For CFS comments, see: http://www.centerforfoodsafety.org/pubs/Dupont%20GAT%20Comments%20FINAL%2012-4-07.pdf.
[115] See USDA website noted above, petition #09-015-01p. Though USDA does not identify the class of herbicides to which these soybeans are resistant, a search on the transformation event turned up a field trial application notice in Japan, where BPS-CV127-9 soybeans are identified as resistant to imidazolinone, one class of ALS inhibitor herbicides; see http://www.bch.biodic.go.jp/english/lmo_2008.html.

In collaboration with the University of Nebraska, Monsanto has developed soybeans that are tolerant to the chlorophenoxy herbicide dicamba.[116] These dicamba-tolerant soybeans are to be stacked with resistance to glyphosate in the context of a joint-licensing agreement with BASF, the largest producer of dicamba.[117] Dicamba-resistant corn and cotton are also projected, ***with potential triple-stacking of herbicide tolerance to dicamba, glyphosate and glufosinate.***[118]

Dow Agrosciences is developing corn and soybeans that are tolerant to the chlorophenoxy herbicide 2,4-D, one component of the Vietnam War defoliant Agent Orange and one of the first widely used herbicides, stacked with tolerance to aryloxyphenoxypropionate grass herbicides of the ACCase inhibitor class. Dow projects introduction of dual 2,4-D/ACCase-tolerant corn in 2012 and 2,4-D/ACCase-tolerant soybeans in 2013 or 2014.[119] The farm press reports that a similar dual-tolerant cotton variety may also be introduced.[120]

Finally, Monsanto and Dow are collaborating to produce "SmartStax" corn, which combines resistance to glyphosate and glufosinate, together with six Bt insecticidal toxins.[121]

There are several indications of the longer-term plans of biotechnology companies with respect to herbicide-tolerant crops. The table below, reproduced from a scientific paper by DuPont-Pioneer scientists, reveals that 12 transgenes conferring resistance to most major classes of herbicides have been developed, and represent likely candidates for a host of new (multiple) herbicide tolerant crops.

Non-glyphosate resistant transgenes that are not currently commercial
(adapted from Reference 48)

Herbicide/herbicide class	Characteristics	Reference
2,4-D	Microbial degradation enzyme	49
Aryloxyphenoxyoxypropionate ACCase inhibitor	Microbial aryloxyalkanoate dioxygenase	50
Asulam	Microbial dihydropteroate synthase	51
Dalapon	Microbial degradation enzyme	52
Dicamba	*Pseudomonas maltophilia*, O-demethylase	45
Hydroxyphenylpyruvate dioxidase (HPPD) inhibitors	Overexpression, alternate pathway, and increasing flux of pathway	53
Phenylurea	*Helianthus tuberosus*, P450	54
Paraquat	Chloroplast superoxide dismutase	55
Phenmedipham	Microbial degradation enzyme	56
Phenoxy acid (auxin)	Microbial, aryloxyalkanoate dioxygenase	50
Phytoene desaturase (PDS) inhibitors	Resistant microbial and Hydrilla PDS	57
Protoporphyrinogen oxidase (PPO) inhibitors	Resistant microbial and *Arabidopsis thaliana* PPO	58

[116] Behrens, M.R. et al (2008). "Dicamba resistance: enlarging and preserving biotechnology-based weed management strategies," *Science* 316: 1185-1188; Service, R.F. (2008). "A growing threat down on the farm," *Science* 316: 1114-1117.
[117] Monsanto (2009). "BASF and Monsanto formalize agreement to develop dicamba-based formulation technologies," Press Release, Jan. 20, 2009, http://monsanto.mediaroom.com/index.php?s=43&item=683
[118] Robinson, E. (2008). "Weed control growing much more complex, new tools coming," Delta Farm Press, March 27, 2008. http://deltafarmpress.com/cotton/weed-control-0327/index.html.
[119] Dow (2007). "Dow AgroSciences reveals progress on new herbicide tolerance trait," August 28, 2007. http://www.dowagro.com/newsroom/corporatenews/2007/20070828a.htm.
[120] Robinson, E. (2008), op. cit.
[121] http://www.monsanto.com/pdf/investors/2007/09-14-07.pdf.

Source: Excerpted from Green et al (2007). "New multiple-herbicide crop resistance and formulation technology to augment the utility of glyphosate," *Pest Management Science* 64(4):332-9.

Likewise, a recent patent assigned to DuPont-Pioneer envisions development of individual herbicide-tolerant crops that tolerate application of seven or more different herbicides.

> "In some embodiments, a composition of the invention (e.g. a plant) may comprise two, three, four, five, six, seven, or more traits which confer tolerance to at least one herbicide, so that a plant of the invention may be tolerant to at least two, three, four, five, six, or seven or more different types of herbicides."[122]

Ongoing field tests involving HT crops:

The table above lists herbicide-resistance transgenes available for developing GE crops with new HT traits, but does not tell us whether these new HT traits are being field-tested in GE crops. CFS undertook an analysis of USDA's GE crop field trial database in an attempt to determine which HT traits/crops are currently undergoing field tests.[123] As of April 7, 2009, there were 812 active permits issued by USDA for GE crop field trials; 283 or 35% involved herbicide-tolerant crops (some of these permits authorized field-testing of other traits in addition to herbicide tolerance). Since some field trial permits authorized field testing of various single-trait HT plants each resistant to different herbicides (e.g. some glyphosate-resistant, others dicamba-resistant), the total number of HT phenotypes was 327. Still other permits involved combinations of 2 or 3 HT traits in the same plant (23 and 4 permits, respectively); when these HT traits are counted separately, the total number of HT traits comes to 358.[124] Of these 358 HT traits, 164 (46%) were glyphosate-resistance, 47 (13%) were dicamba-resistance, 24 (7%) were glufosinate-resistance,[125] and 18 (5%) ALS inhibitor-resistance.[126] Interestingly, a significant proportion of HT traits (105 or 29%) were labeled as "confidential business information" (CBI) or otherwise not specified (e.g. the phenotype entry was merely "herbicide tolerance" or "agrichemical tolerance").

Active HT crop field trial permits involve 12 crops, though the great majority of permits (91%) are for HT soybeans (118), HT corn (99), HT cotton (23) and HT alfalfa (19). Of the 283 permits, 242 (85.5%) were granted to one of the big 6 biotechnology/ agrichemical firms:

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[122] "Novel Glyphosate-N-Acetyltransferase (GAT) Genes," U.S. Patent Application Publication, Pub. No. US 2009/0011938 A1, January 8, 2009, paragraph 33.

[123] Two searches conducted at http://www.isb.vt.edu/cfdocs/fieldtests1.cfm. All active permits for GE crop field trials determined on 4/7/09 by checking the "phenotype category" on first page, then selecting all phenotype categories and "field test permits currently in effect" and "short record" on the next page. For active HT crop field trials, search conducted on 4/5/09 by checking "phenotype category" on first page and "herbicide-tolerance," "field test permits currently in effect" and "full record" on the next webpage. Permits with "status" of "withdrawn" or "denied" were excluded from the analysis of both total active field trials and active HT crop field trials.

[124] It is important to note that the relatively few field trials involving plants with multiple (2 or 3) HT traits does ***not*** indicate correspondingly little interest in developing multiple HT crops. USDA "deregulation" of a single-trait HT crop event covers any progeny of that event, including conventional crosses with any other already deregulated HT crop. Thus, multiple HT crops can come to market without undergoing a separate deregulation process.

[125] Includes entries for phosphinothricin tolerance and one for "bar gene." Phosphinothricin is an alternate name for glufosinate, and the bar gene confers resistance to phosphinothricin.

[126] Includes entries for imidazolinone- and sulfonylurea-tolerance, since these are types of ALS inhibitor herbicides.

Monsanto (112), Dow (46), DuPont-Pioneer (42), Syngenta (18), Bayer (18), and BASF (6). The remainder were granted to smaller private firms (33) or universities (8).

The fact that over one-third (35%) of active GM crop field trial permits involve HT crops indicates continuing strong interest in this trait category among GE crop developers, underscoring the need for APHIS to deal comprehensively with HT crops in its revised rules. It is interesting to note the preponderance of glyphosate-tolerance in active HT field trial permits. This – and the entry into the glyphosate-resistance market of DuPont-Pioneer and Bayer noted above – indicates strong interest in deploying new crops with glyphosate-resistance, despite the growing problem of glyphosate-resistant weeds. We can infer from this that selection pressure for GR weeds will at the very least maintain its current high levels, and probably increase in the near- to medium-term future. Although only 4 HT traits are listed in USDA's database, the large number of "confidential" or otherwise unspecified HT traits (105 or 29%) indicates that GE crops with resistance to other herbicides (perhaps some of those listed in the table above) are being field-tested. Interestingly, the HT trait in all of Dow's 46 active field trial permits for HR crops (involving corn, soybeans, cotton and tobacco) was labeled CBI. Based on the information presented above, many of these HT crops are likely to be 2,4-D-resistant. Other companies also hid the identity of HT traits they are field-testing, including Bayer (19 permits), Syngenta (17) and Monsanto (15).

5) Consequences of enhanced glyphosate and multiple herbicide tolerant crop systems

Enhanced glyphosate tolerance in crops will likely accelerate the expansion of and level of resistance in glyphosate-resistant weeds, undermining the efficacy of this herbicide

Roundup Ready cropping systems have fostered overreliance on glyphosate for weed control. This overreliance has given rise to sharply expanding acreage infested with glyphosate-resistant weeds. Growers were encouraged to rely exclusively on glyphosate by Monsanto,[127] whose scientists discounted the possibility of glyphosate-resistant weed evolution.[128] Surprisingly, APHIS continues to repeat this abundantly disproven myth that weeds are not likely to develop resistance to glyphosate, or to do so only slowly, in the draft PEIS.[129] Despite repeated exhortations from weed scientists (and, belatedly, by Monsanto and other biotech companies) to use multiple herbicides to slow evolution of resistance to glyphosate, many growers have been reluctant to do so. Surveys still show fairly high levels of exclusive reliance on glyphosate for weed control in soybeans (40-50%) and lesser but still substantial dependence on glyphosate alone in cotton (about 20% of farmers).[130]

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[127] Shaner, D.L. (2000). "The impact of glyphosate-tolerant crops on the use of other herbicides and on resistance management," Pest Management Science 56: 320-26.

[128] Bradshaw LD, Padgette SR, Kimball SL and Wells BH, Perspectives on glyphosate resistance. *Weed Technol* **11**:189–198 (1997).

[129] USDA APHIS (2007). Introduction of Genetically Engineered Organisms, Draft Programmatic Environmental Impact Statement, July 2007. See pp. 119-121 for the thoroughly inadequate discussion of herbicide-tolerant crops, which fails to even name a single glyphosate-resistant weed population in the US.

[130] Foresman, C, Glasgow, L. (2008). "US grower perceptions and experiences with glyphosate-resistant weeds," Pest Management Science.

The enhanced tolerance to glyphosate discussed above enables farmers to apply higher rates of glyphosate, which in turn will encourage a delay in glyphosate application until weeds become larger.[131] (Higher doses allow larger weeds to be killed.) In the case of Roundup Ready Flex cotton, the ability to apply glyphosate throughout the crop's lifespan further facilitates this practice. Delaying application in turn increases the likelihood that weeds, including any resistant individuals that are present in the population, will mature to produce pollen and set seed. Pollen and seed carrying the resistance trait will spread it spatially (through cross-pollination with susceptible weeds) and temporally (seeds with resistance trait entering the seed bank). This helps explain why weed experts continually exhort farmers to control weeds when they are small, and NOT to delay application until they are larger.

The short-term fix of enhanced glyphosate tolerance will thus faciliate continued postponement of the diversification of weed management practices (including non-chemical options[132]) that all agree is essential to save glyphosate as a viable weed control tool. Enhanced glyphosate resistance will thus likely have the effect of accelerating the rate of increase of glyphosate-resistance in weeds, and the demise of glyphosate as an effective weed control agent.

Some argue that combining glyphosate tolerance with tolerance to one or more additional herbicides provides the opportunity for better control of weeds resistant to any one of the HT crop-associated herbicides, in particular GR weeds.[133] However, there are several problems with this line of thinking. First, it is very unclear whether growers will make much use of any non-glyphosate herbicides to which the crop is tolerant, at least in the near-term, especially if enhanced glyphosate tolerance gives the grower the option of applying higher rates of glyphosate. The predilection for sticking with glyphosate will be especially strong in those crops that combine tolerance to glyphosate and ALS inhibitors. ALS inhibitor use on corn and especially soybeans has dropped off sharply in recent years,[134] in part due to massive evolution of ALS inhibitor-resistant weeds (see Figure 4). In fact, it is well established that the widespread inefficacy of many ALS inhibitors was one factor driving adoption of Roundup Ready crops.[135] In addition, because the ALS inhibitor resistance trait has little or no fitness costs in many weed species,[136] many of the resistant weeds reported in the late 1980s and early 1990s likely retain their resistance, further discouraging use of ALS inhibitors. Some reports even suggest that ALS

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[131] Green et al (2007). "New multiple-herbicide crop resistance and formulation technology to augment the utility of glyphosate," *Pest Management Science* 64(4):332-9. Green et al suggest a money- and time-saving motive for this practice: "Many growers waited until the weeds were large in the hope that all the weeds had emerged and only one application would be needed."

[132] Owen, MDK (2008), op. cit. Owen discusses crop rotation as one non-chemical method to mitigate weed resistance.

[133] Green et al (2007), op. cit.

[134] See discussions in CFS comments on DuPont-Pioneer's Optimum GAT soybeans and corn, cited above, which reference USDA NASS data on percent of overall acres of each crop treated with ALS inhibitor herbicides. The decline in acres treated with ALS inhibitors is particularly sharp with soybeans, but is also occurring with corn.

[135] Owen & Zelaya (2005). "Herbicide-resistant crops and weed resistance to herbicides," *Pest Management Science* 61: 301-311.

[136] Powles & Preston (2006), "Evolved glyphosate resistance in plants: hiochemical and genetic basis of resistance," *Weed Technology* 20: 282-289, see p. 285.

inhibitor-resistant weeds can have ***enhanced*** fitness in the absence of selection pressure from ALS inhibitor use.[137]

Multiple herbicide-resistant weeds

The likely tendency of growers to make preferential use of glyphosate on dual glyphosate/ALS inhibitor-tolerant crops will continue to exert selection pressure for development of dual-HR weeds. This is particularly true of common waterhemp, which has massive populations resistant to ALS inhibitor herbicides throughout the Midwest (up to 5.1 million acres, according to WSSC-HRAC, but possibly much more). Thus, such dual-tolerant crops will likely do little if anything to stem the steep rise in glyphosate use with dramatically increasing adoption of RR corn. WSSC-HRAC currently list three biotypes of weeds that already possess dual glyhosate/ALS inhibitor-resistance: a population of resistant horseweed in Ohio that infest up to 500 acres; a population of dual-resistant common waterhemp in Illinois; and a population of triple-resistant common waterhemp infesting up to 10,000 acres in Missouri (also resistant to PPO inhibitors). The resistance to the PPO inhibitors developed, predictably, from use of PPO inhibitors to kill waterhemp that had become resistant to ALS-inhibitors.[138] Both Missouri and especially Illinois have million acre infestations of ALS-inhibitor-resistant common waterhemp. The problem could become much worse. One Midwestern weed expert has heard anecdotal reports from farmers of inconsistent control of common waterhemp with glyphosate. He confirmed substantial inherent variability in the susceptibility to glyphosate (18-fold) in an Iowa population of common waterhemp, was able to select for populations with decreased sensitivity to glyphosate, and concluded that: "the potential for the evolution of glyphosate resistance is significant." He further noted that the potential for glyphosate resistance "is relevant as most *A tuberculatus* [waterhemp] populations in the Midwest are suspected to be resistant to ALS-inhibiting herbicides and ***further selection pressure by glyphosate may select for multiple-resistant populations.***"[139]

Multiple herbicide resistance in this weed is of great concern because waterhemp is considered the number one weed problem for Illinois corn and soybean growers, in part because of its ability to grow 2-3 meters tall, emerge over an extended period of time late into the growing season, and substantially decrease corn yields even at relatively low levels of infestation.[140]

We have noted the emergence of several new populations of multiple-herbicide resistance weeds above, and cited weed experts as projecting many more arising in the near future, in connection with HT crop systems.

Burnout of glyphosate, followed by weeds resistant to other HT-crop associated herbicides

In the longer term, the burnout of glyphosate as an effective weed control tool will likely drive adoption of crops genetically engineered for tolerance to dicamba, 2,4-D and other herbicides, in

[137] Tranel & Wright (2002). "Resistance of weeds to ALS-inhibiting herbicides: what have we learned?" *Weed Science* 50: 700-712, see p. 706.
[138] Owen & Zelaya (2005), op. cit.
[139] Zelaya & Owen (2005). "Differential response of *Amaranthus tuberculatus* (Moq ex DC) JD Sauer to glyphosate," *Pest Manag Sci* 61: 936-950.
[140] Steckel & Sprague (2004). "Common waterhemp (*Amaranthus rudis*) interference in corn," *Weed Science* 52: 359-64.

turn spawning new waves of weeds resistant to those herbicides. In short, the "pesticide treadmill" will be likely be accelerated by the "transgenic treadmill."[141]

6) Health consequences of herbicide-tolerant crop systems

In prior comments on this rulemaking and elsewhere, CFS has pointed to the adverse health and environmental impacts of increasing herbicide use, including glyphosate. If crops tolerant to dicamba, 2,4-D and other herbicides become prevalent, we can expect substantial increases in their use, as glyphosate use has exploded with proliferation of Roundup Ready crops. This in turn will lead to exacerbation of negative health impacts on farmers/farmworkers who apply these pesticides. Two near-term HT crop systems described above involve tolerance to dicamba and 2,4-D, which are members of the class of chlorophenoxy herbicides and are well-known to have carcinogenic and/or endocrine disrupting activity.

> "Dicamba is an old, relatively high-risk herbicide. It is genotoxic (damages the DNA in cells) and has been linked to elevated rates of cancer among farm populations. It is mobile in soils and prone to leaching to groundwater. Dicamba is moderately persistent and will no doubt trigger a host of environmental problems if its use jumps 10-fold or more, as is likely if dicamba resistant soybeans are widely adopted."[142]

According to anecdotal reports from several farmers, dicamba, once applied, is very prone to being lifted and carried by the wind, in some cases for a mile or more, to damage other plants and crops. Human exposure to revolatized, drifting dicamba is of course also likely. Increased use of dicamba from adoption of dicamba-resistant soybeans could thus have both negative health impacts as well as serious agronomic and economic impacts on neighboring growers, including crop damage and associated economic losses. It might also lead to costly "defensive" adoption of dicamba-resistant crops not from desire to make use of the trait, but rather for protection against damage that would otherwise be caused by dicamba drift. Glyphosate spray drift has had serious negative impacts on neighboring non-Roundup Ready growers, and some farmers reportedly purchase Roundup Ready crops for precisely such "defensive" reasons.[143] Arkansas state officials were or are considering regulations to minimize glyphosate spray drift damage to non-RR crops.[144] Needless to say, many other herbicides likely pose similar drift threats to neighboring growers.

2,4-D is another chlorophenoxy herbicide that has been associated with a number of adverse health impacts on agricultural workers who apply it: increased risk of cancer, particularly non-

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[141] Binimelis, R., et al. "Transgenic treadmill": Responses to the emergence and spread of glyphosate-resistant johnsongrass in Argentina. Geoforum (2009), doi:10.1016/j.geoforum.2009.03.009.

[142] Excerpted from: Organic Center (2007). "Dicamba-resistant soybeans to the rescue?" The Organic Center, June 2007, http://www.organic-center.org/science.hot.php?action=view&report_id=96. For an account of dicamba's adverse health impacts , see Cox, C. (1994). "Dicamba Fact Sheet," Journal of Pesticide Reform 14(1), Spring 1994, at: http://www.pesticide.org/dicamba.pdf.

[143] Arax, M. and J. Brokaw (1997). "No Way Around Roundup," *Mother Jones*, January/February 1997. http://www.motherjones.com/news/feature/1997/01/brokaw.html.

[144] Bennett, D. (2007). "A difference of opinion: glyphosate drift and formulations," *Delta Farm Press*, January 29, 2007. http://deltafarmpress.com/news/070129-glyphosate-drift/index.html

Hodgkin's lymphoma, and increased rate of birth defects in children of men who apply the herbicide. 2,4-D is also a suspected endocrine disruptor.[145]

The State of California has recently placed the entire class of chlorophenoxy herbicides on its "toxics" list as probable human carcinogens.[146]

HR crops mean greater exposure to HR crop-associated herbicides:
A little-discussed consequence of "over-the-top" herbicide application to HR crops (for the most part impossible with herbicides used with conventional crops) is increased livestock exposure to the HR crop-associated herbicide in feed, and perhaps, at least in some cases, increased human exposure to residues of the herbicide in foods. Biotech companies have obtained new or increased herbicide "tolerances" (maximum allowable residues) from EPA to facilitate introduction of certain HR crops. For instance, at the request of Aventis CropScience (now Bayer CropScience), EPA established new tolerances for residues of glufosinate on food and feed products derived from transgenic versions of canola, cotton, corn, rice, soybean and sugar beet.[147] These tolerances were obtained specifically for Bayer's glufosinate-tolerant, LibertyLink versions of these crops. Monsanto has obtained from the EPA numerous tolerance increases for glyphosate residues associated with its Roundup Ready crops, including: from 6 ppm to 20 ppm for soybeans (raw agricultural commodity) several years before the commercial introduction of Roundup Ready soybeans;[148] from 0.2 ppm for sugar beets (as a whole) to 10, 10 and 25 ppm for sugar beet roots, tops and dried pulp, respectively, a few months after deregulation of the first Roundup Ready sugar beets;[149] and from 75 ppm to 175 ppm for alfalfa forage and 200 ppm to 400 ppm for alfalfa hay several years prior to Monsanto's first attempt to gain nonregulated status for Roundup Ready alfalfa in 2003.[150] In December 2008, EPA granted DuPont's request to amend existing glyphosate tolerances to include the N-acetyl-glyphosate metabolite produced by the GAT enzyme incorporated into its GAT soybeans and corn, and to substantially increase the (thus amended) glyphosate tolerance for aspirated grain fractions (fragments or dust of grain, often fed to beef livestock) from 200 to 310 ppm. This same rule also appears to increase glyphosate tolerances for a variety of meat byproducts.[151] As noted

[145] For more, see "2,4-D: chemicalWATCH Fact Sheet," Beyond Pesticides, at: http://www.beyondpesticides.org/pesticides/factsheets/2,4-D.pdf. For restrictions on residential use of 2,4-D in various countries, see: http://en.wikipedia.org/wiki/2,4-D.
[146] Daily Green (2009). "30 'new' toxic chemicals to avoid," Daily Green, June 17, 2009. http://www.thedailygreen.com/environmental-news/latest/toxic-chemicals-47061601
[147] EPA (2003). Glufosinate-Ammonium; Pesticide Tolerance. *Federal Register*, Vol. 68, No. 188, Sept. 29, 2003: 55833-55849. It is interesting to note that EPA's tolerances apply only to ***transgenic*** versions of these crops.
[148] EPA RULE (1992). "Pesticide Tolerances and Food and Feed Additive Regulations for Glyphosate," Final Rule, *Federal Register*, Sept. 16, 1992, Vol. 57: 42700.
[149] EPA (1999). "Glyphosate; Pesticide Tolerance," Final Rule, Federal Register, April 14, 1999, Vol. 64, No. 71: 18360-18367.
[150] For old and new tolerances, respectively, see table at end of following rules: EPA (2000a). "Glyphosate; Pesticide Tolerance," Final Rule, Federal Register, Aug. 30, 2000, Vol. 65, No. 169: 52660-52667, http://www.epa.gov/EPA-PEST/2000/August/Day-30/p22168.htm; EPA (2000b). "Glyphosate; Pesticide Tolerance," Final Rule, Federal Register, Sept. 27, 2000, Vol. 65, No. 188: 57957-57966, http://www.epa.gov/EPA-PEST/2000/September/Day-27/p24318.htm.
[151] EPA (2008). "Glyphosate; Pesticide Tolerances," Final Rule, *Federal Register*, Dec. 3, 2008, Vol. 73, No. 233: 73586-73592; for old glyphosate tolerance for aspirated grain fractions and for various meat products, see EPA (2000b), op. cit. One problem in tracking glyphosate tolerances for specific items over time is the EPA's frequent reshuffling of tolerance categories.

above, the introduction of Roundup Ready Flex cotton was associated with a label change recommending 50% higher glyphosate application rates, while GlyTol cotton was associated with a glyphosate tolerance increase on cotton gin byproducts.

Based on this history, one can expect biotech companies to seek new and/or increased tolerances for the herbicides associated with new (multiple) HR crops as they come closer to commercial introduction. We note that multiple HR crops could easily have increased residues of two or more different herbicides, raising additional food and feed safety concerns (e.g. potential adverse synergistic effects of multiple herbicide residues).[152]

Multiple herbicide-resistant crops represent largely unchartered territory that requires careful assessment and regulation

Many weed scientists predicted little or no development of glyphosate-resistant weeds in the early and mid 1990s, prior to the introduction of Roundup Ready soybeans.[153] These optimistic predictions have been proven decisively wrong by events in the field, and should serve as a cautionary tale in assessments of the potential of enhanced glyphosate-tolerant and multiple herbicide-resistant crop systems to foster expanding populations of (multiple) herbicide-resistant weeds, and further increases in herbicide use, with negative environmental, human health and agronomic consequences.

7) Recommendations for APHIS regulation of HT crop systems

APHIS regulates GE crops under the Plant Protection Act (PPA). The PPA endows APHIS with the statutory authority to regulate practices that lead to the introduction and propagation of noxious weeds, for instance, importation or interstate movement of materials that may harbor seeds or other viable parts of weeds deemed noxious.

In these supplementary comments and prior comments on this rulemaking, CFS has demonstrated the clear propensity of HT crop systems (cultivation of an HT crop and associated herbicide application practices) to foster the rapid evolution and propagation of herbicide-resistant weeds that can be extremely aggressive, injurious to the interests of agriculture, and much more difficult to control or manage than the non-herbicide-resistant version of the same weed species. CFS has also presented case studies of several herbicide-resistant weeds ***that would not exist absent the introduction and unregulated use of the associated herbicide-tolerant crop systems, and which pose serious threats to the interests of agriculture.*** The case study of glyphosate-resistant Palmer amaranth, in particular, demonstrates the noxious character of an herbicide-resistant weed that owes its existence and massive propagation directly to the unregulated use of glyphosate-tolerant crop systems, and which is regarded by agronomic

[152] For a brief discussion, see: Center for Food Safety's comments on USDA's Programmatic Environmental Impact Statement on GM crops, pp. 59-61, at http://www.centerforfoodsafety.org/pubs/USDA%20PEIS%20Comment%20Master%20FINAL%20-%209%2011%2007.pdf

[153] Waters, S. (1991). "Glyphosate tolerant crops for the future: development, risks, and benefits," Proceedings of the Brighton Crop Protection Conference: Weeds 165-170; Jasieniuk M, Constraints on the evolution of glyphosate resistance in weeds. *Resistant Pest Manag Newslett* **7**:31–32 (1995); Bradshaw LD, Padgette SR, Kimball SL and Wells BH, Perspectives on glyphosate resistance. *Weed Technol* **11**:189–198 (1997); Watkinson et al (2000). "Glyphosate-resistant crops: history, status and future," Pest Manag. Sci. 61: 219-224.

experts as presenting a serious threat to the viability of continued cotton production in the United States.

CFS encourages APHIS to exercize its noxious weed authority to assess, and regulate as needed, herbicide-tolerant crops and associated herbicide application practices (i.e. HT crop systems). Such regulation could take several forms, including:

1) Reject petitions for deregulation in those cases where the unregulated use of HT crop systems pose threats to the interests of agriculture, the environment, and/or human health, including the health of pesticide applicators. This regulatory option should be chosen when a cumulative assessment of the HT crop proposed for deregulation against the backdrop of existing HT crops demonstrates a significantly increased risks for increased herbicide use, accelerated development of noxious resistant weeds, increased weed control costs, etc.

2) Allow commercial cultivation of HT crop systems, but with appropriate restrictions and continuing regulatory authority, to mitigate potential risks. For instance, APHIS could:
   a) Impose "stacking" restrictions disallowing the combination of the GE crop event at issue with other GE crop events when such stacking would lead to unacceptable outcomes – e.g. enhanced glyphosate tolerance from combination of multiple modes of action of glyphosate tolerance, contributing to the "burnout" of glyphosate as an effective weed control tool;
   b) Geographic restrictions to disallow cultivation of the HT crop in areas where it would exacerbate existing problems re: excessive pesticide use and resistant weed evolution; and
   c) Mandatory monitoring for evolution of resistant weeds by university or other independent agronomic experts, with continuing regulatory authority to mitigate risks if and as they arise. A recommendation similar to this was recently recommended by the Government Accountability Office.[154]

3) Designate herbicide-resistant biotypes of weed species as federally-listed noxious weeds, in those cases where herbicide resistance confers upon the otherwise less problematic weed characteristics that raise it to the status of noxious. Designation of herbicide-resistant biotypes as noxious weeds should be accompanied by regulatory controls and restrictions, as needed, on the HT crop systems that accelerate the evolution of such weeds.

4) Mandatory herbicide-resistant weed management plans, to forestall or slow the development of weed resistance to HT crop-associated herbicide(s). The EPA's resistance management program for GE insect-resistant crops offers a valuable model for APHIS in this regard. To this end, APHIS should revive its moribund collaboration with EPA on developing herbicide-resistant weed management plans for each and every HT crop that is considered for commercial cultivation.

[154] GAO (2008). "Genetically engineered crops: Agencies are proposing changes to improve oversight, but could take additional steps to enhance coordination and monitoring," Report to the Committee on Agriculture, Nutrition, and Forestry, U.S. Senate, U.S. Government Accountability Office, GAO 09-060, Nov. 2008, pp. 30-31.

5) APHIS should also confer with sister USDA agencies, such as the Agricultural Research Service, to better coordinate its regulatory practices with ongoing research activities. For instance, ARS's Action Plan: 2008-2013 (cited above) has significant components related to the mitigation and management of pesticide resistance, including herbicide-resistant weeds. These research initiatives include development of non-chemical weed control techniques, as are also being explored by academic scientists.[155] It makes no sense for APHIS to make decisions that lead to exacerbation of threats like herbicide-resistant weeds to which its sister agencies are seeking solutions.

6) APHIS should also seek input from independent agronomic experts to better inform its rule-making with respect to biotech crops, as recommended by a National Academy of Sciences committee in 2002, and as promised by former APHIS Administrator Bobby Accord.

[155] As one example, for use of cover crops to mitigate GR Palmer amaranth, see: Culpepper, S. and J. Kichler (2009), op. cit.; and Robinson, E. (2008c). "Weed control growing much more complex, new tools coming," Delta Farm Press, March 27, 2008.

Center for Food Safety Work Product – May 2010

Herbicide-Tolerant Crops in the Near-Term Pipeline as of May 3, 2010

http://www.aphis.usda.gov/brs/not_reg.html

The glyphosate-resistant weed epidemic triggered by continual glyphosate use with Roundup Ready crops is driving the pesticide-biotech industry's product pipeline. Below, eight HT crops pending deregulation (i.e. approval for commercial cultivation) by USDA, some resistant to 2 or 3 herbicide classes. In addition, 5 of the 8 GE crops deregulated since 2005 have been herbicide-resistant. See next pages for further information.

Petition No.	Company	Crop / Transf. Event	Phenotype	Comments
Eight Herbicide-Tolerant Crops Pending Grant of Nonregulated Status by USDA as of May 3, 2010				
09-349-01p	Dow	Soybean DAS-68416-4 (see below)	Triple herbicide tolerant	Tolerates 3 classes of herbicide: phenoxy auxins (e.g. 2,4-D, MCPA), aryloxyphenoxypropionates (ACCase inhibitors) and glufosinate. 2,4-D was part of the dioxin-laced, Vietnam War defoliant Agent Orange, and is strongly linked to increased incidence of cancer in pesticide applicators.
09-328-01p	Bayer	Soybean FG72	Double herbicide tolerant	Tolerates glyphosate and HPPD inhibitors. Bayer, like Stine Seed and DuPont (see below) have developed their own glyphosate-tolerant crops, a development that will hasten the already rapid emergence of glyphosate-resistant weeds.
09-233-01p	Dow	Corn DAS-40278-9	Double herbicide tolerant	Tolerates phenoxy auxins (e.g. 2,4-D, MCPA) and aryloxyphenoxypropionates (ACCase inhibitors). 2,4-D was part of the dioxin-laced, Vietnam War defoliant Agent Orange, and is strongly linked to increased incidence of cancer in pesticide applicators.
09-063-01p	Stine Seed	Corn HCEM485	Glyphosate tolerant	Appears to be a variation on Monsanto's glyphosate-insensitive CP4 EPSPS enzyme. As Monsanto's competitors introduce glyphosate-tolerant crops, there will be fewer conventional, non-glyphosate-tolerant options.
09-015-01p	BASF	Soybean BPS-CV127-9	Imidazolinone-tolerant	Imidazolinones are a class of ALS inhibitor herbicides. More species of weed have developed resistance to ALS inhibitors than to any other family of herbicides. A damaging corn weed (common waterhemp) resistant to glyphosate, ALS inhibitors and one or two other herbicide classes has evolved in Missouri (triple-resistant) and Illinois (quad-resistant).
08-340-01p	Bayer	Cotton T304-40XGHB119	Glufosinate tolerant; insect resistant	Bayer is the developer of a glufosinate-tolerant, LibertyLink line of crops that the company is marketing as a way for farmers to tackle glyphosate-resistant weeds. As with other herbicide-tolerant crop offerings, the likely result is weed populations resistant to multiple herbicides.
04-110-01p	Monsanto & Forage Genetics	Alfalfa J101, J163	Glyphosate tolerant	In 2006, a federal district court reversed USDA's original approval of Roundup Ready alfalfa; once again being considered for deregulation after a court-ordered, but deeply flawed, Environmental Impact Statement
03-104-01p	Monsanto & Scotts	Creeping bentgrass ASR368	Glyphosate tolerant	In 2006, a federal district court ruled that USDA's failure to assess field trials of glyphosate-tolerant creeping bentgrass for environmental impacts violated federal law. Research by EPA has shown pollen and seeds from such field trials can travel for miles, resulting in weedy glyphosate-resistant hybrids and bentgrass plants that cannot be killed with glyphosate.

Dow Agroscience's triple herbicide-resistant DAS-68416-4 soybeans

* USDA describes these soybeans as "2,4-D and glufosinate tolerant."[1] This description is not quite accurate. A search on the event name "DAS-68416-4," a unique identifier, turns up a Japanese field trial application with the following information (http://www.bch.biodic.go.jp/download/en_lmo/DAS68416enUR.pdf):

  "Soybean tolerant to aryloxyalkanoate herbicide and glufosinate herbicide (Modified aad-12, pat, Glycine max (L.) Merr.)"

* Aryloxyalkanoates are a broad cross-cutting class of herbicides that include some ACCase inhibitors (i.e. aryloxyphenoxypropionates) as well as phenoxy auxin herbicides like 2,4-D and MCPA. Thus, these soybeans are resistant to herbicides from at least three different herbicide families (ACCase inhibitors, phenoxy auxins and glufosinate: see below under "Corn DAS-40278-9").

Dow Agroscience's dual herbicide-tolerant DAS-40278-9 corn

* USDA describes this corn as "2,4-D and ACCase-inhibitor tolerant" (see footnote 1). In fact, it contains the same aryloxyalkanoate herbicide tolerance as Dow's triple herbicide-resistant soybeans (see above), lending this corn resistance to phenoxy auxins like 2,4-D and many but not all ACCase-inhibiting herbicides. A search on the event name "DAS-40278-9," a unique identifier, turns up the following abstract.

http://www.weeds.iastate.edu/NCWSS2009/Abstracts/011.pdf
PERFORMANCE OF DOW AGROSCIENCES HERBICIDE TOLERANCE TRAIT IN CORN.
Mark A. Peterson, David M. Simpson, Cory Cui, Eric F. Scherder, David C. Ruen, John S. Richburg, Sam M. Ferguson, Patricia L. Prasifka and Terry R. Wright, Dow AgroSciences, Indianapolis, IN 46268.

Dow AgroSciences has introduced two new herbicide tolerance traits, commonly referred to Dow AgroSciences Herbicide Tolerance (DHT) traits. DHT1 trait is currently being developed in corn. The DHT1 trait is a synthetic gene developed by Dow AgroSciences from *Sphingobium herbicidovorans*. *In planta* this gene produces an enzyme that metabolizes several herbicides having an aryloxyalkanoate moiety, including Phenoxy auxins (e.g., 2,4-D, MCPA) and aryloxyphenoxypropionates (e.g., quizalofop, haloxyfop). **DHT1 corn events have been tested in the field and demonstrated robust tolerance to preemergence, single postemergence, and sequential postemergence applications of 2,4-D at 1120, 2240 and 4480 g ae/ha [Note from B. Freese: These rates, expressed in grams of acid equivalents per hectare, are equivalent to 1, 2 and 4 lbs. per acre, respectively, a hefty dose of 2,4-D, given that 2,4-D is typically applied a rates of 0.3 to 1 lb. per acre, as can be verified by searching on 2,4-D at http://www.pestmanagement.info/nass/app_usage.cfm].**

Postemergence applications of quizalofop of up to 184 g ai/ha have also been well tolerated by

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[1] See http://www.aphis.usda.gov/brs/not_reg.html.

DHT1 corn events. Corn growth, development, maturity and yield of individual events are equivalent to iso-lines. DHT1 may also be stacked with other herbicide resistance traits to improve and enhance the performance of current weed control systems, improve the control of "hard to kill" broadleaf weeds, and prevent or delay the onset of herbicide resistant weeds.

Bayer CropScience's FG72 soybeans:

* USDA describes these soybeans as "glyphosate and isoxaflutole tolerant" (see ft. 1). A search on the event name "FG72," a unique identifier, turns up http://www.inspection.gc.ca/english/plaveg/bio/subs/2010/20100317e.shtml, which has the following information:

* The CFIA and Health Canada have received a submission from MS Technologies LLC and Bayer CropScience Inc. seeking an approval for unconfined environmental release (including for import purposes) and livestock feed and food use of soybean designated as **Double-Herbicide-Tolerant Soybean Event FG72**, which has been **genetically engineered for tolerance to glyphosate and HPPD inhibitor herbicides**.

* Isoxaflutole is one of several herbicides of the HPPD inhibitor class, which act by depleting plant tissues of protective pigments, resulting in bleaching of young tissue which leaves the plant vulnerable to damage by light. HPPD inhibitors are one of only two classes of herbicides (the other being glutamine synthetase inhibitors (glufosinate)) to which weeds have yet to evolve resistance, but weed scientists are very concerned that resistance to this class will evolve as well. Making a plant tolerant to an herbicide is an invitation for over-reliance on that pesticide to the exclusion of other weed control methods, chemical or cultural. Cultural methods of weed control – too little used, often ignored by extension agents and farmers alike – include planting of cover crops that exude allelopathic compounds that suppress weeds quite effectively in follow-on crops, and crop rotations that break weed cycles and are advisable for other reasons.

BASF Plant Science's BPS-CV127-9 Soybean

* USDA lists these soybeans as "imidazolinone tolerant" (see ft. 1)

* Imidazolinones are one class of acetolactate synthase (ALS) inhibiting herbicides. Multiple populations of 108 species of weeds have evolved resistance to ALS inhibitors worldwide, more than to any other family of herbicides. See: http://www.weedscience.org/Summary/UspeciesMOA.asp?lstMOAID=3&FmHRACGroup=Go and http://www.weedscience.org/ChronMOA.GIF

* The first ALS inhibiting herbicide was introduced in 1982, followed by the first report of weed resistance just five years later in 1987. Rapid adoption of Roundup Ready crops beginning in the 1990s was in part due to widespread weed resistance to ALS inhibitors – a classic example of the pesticide treadmill: See: Benbrook (2009). "Impact of Genetically Engineered Crops on Pesticide Use: The First 13 Years," The Organic Center, November 2009, pages 12-14, Figure 2.4. http://www.organic-center.org/science.pest.php?action=view&report_id=159.

Other herbicide-resistant crops from Monsanto and collaborators:

* SmartStax corn from Monsanto and Dow, introduced this year, are resistant to glyphosate and glufosinate (i.e. Liberty or a new formulation called Ignite, from Bayer CropScience)

* Dicamba-tolerant soybeans from Monsanto, in collaboration with BASF, the largest manufacturer of dicamba. See: Behrens, M.R. et al (2008). "Dicamba resistance: enlarging and preserving biotechnology-based weed management strategies," *Science* 316: 1185-1188; and Service, R.F. (2007). "A growing threat down on the farm," *Science* 316: 1114-1117. In this latter article, eminent weed scientist Stephen Powles predicts that glyphosate-resistant weeds will reach epidemic proportions in a few years time. The future is now.

* Dicamba-tolerance will be stacked with glyphosate tolerance. See "BASF and Monsanto formalize agreement to develop dicamba-based formulation technologies," Press Release, Jan. 20, 2009, http://monsanto.mediaroom.com/index.php?s=43&item=683

* The potential for vastly increased use of dicamba is concerning because of "revolatilization" issues. Dicamba, once applied, will under the right conditions revolatilize and drift long distances, damaging neighboring crops. For more on the revolatilization issue, contact David Mortensen, Penn State weed scientist, who is conducting research on this matter: Phone: 814-865-1906; E-mail: dmortensen@psu.edu

* Dicamba- & Glufosinate-tolerant corn, which would apparently also be glyphosate-tolerant, for triple herbicide resistance: "This next-generation herbicide-tolerant corn product builds on the Roundup Ready® platform and would provide farmers with additional herbicide tolerance options. See: http://monsanto.mediaroom.com/index.php?s=43&item=788

* Triple resistant cotton: Dicamba, glufosinate, and glyphosate: see http://monsanto.mediaroom.com/index.php?s=43&item=788

* Corn tolerant to "FOPS" herbicides and glyphosate. FOPS is shorthand for aryloxyphenoxypropionates (see Dow triple-resistant soybeans and dual-resistant corn above). FOPS are considered "high resistance risk" herbicides due to rapid evolution of weed resistance with their use. For example, see: http://www.efarming.com.au/News/announcements/2269/dim-future-for-fop-herbicides-in-wa.html and http://www.hgca.com/publications/documents/cropresearch/Paper_12_Stephen_Moss.pdf

Letter appended to Monsanto's petition for nonregulated status for Roundup Ready soybeans (1993) in which Michael Owen suggests that cultivation of RR soybeans will not foster glyphosate-resistant weeds

IOWA STATE UNIVERSITY

University Extension

February 5, 1993

Ms. Diane Re
Monsanto Company
700 Chesterfield Parkway North
Chesterfield, MO 63198

Dear Ms. Re:

Dr. Emilio Oyarzabal requested that I write to you and address several issues concerning the development of glyphosate-resistant soybeans. I have conducted research for one year on these soybeans and feel strongly that this research should continue. It was suggested that I comment on three issues: the development of weed resistance, weed population shifts and overwintering of soybean seed.

Based on the biological and chemical properties demonstrated by glyphosate, it is my opinion that suggested glyphosate use patterns that would develop as the result of glyphosate-resistant soybeans would not result in the development of a resistant weed population. Care should be taken, however, to inform growers that misuse of glyphosate could theoretically result in a resistant weed population. The same could be said for all commercially available herbicides.

Similarly, the use of glyphosate and glyphosate-resistant soybeans will not greatly influence any weed population shifts. Given weed seed dormancy, the soil-seedbank will influence the weed populations more than the judicial use of any herbicide, regardless of the crop genetics. It is important to recognize that soybeans are traditionally grown in rotational schemes that would allow only one year of soybeans consecutively.

Finally, there is no likelihood that soybean seeds will overwinter in the soil. Seed dormancy is a negative trait in crop seed and is bred out of the seed lines. Further, soybeans are self-pollinated. Thus, there is no likelihood that any seed that "volunteered" would ever cross. Importantly, there are no native species with which a soybean could hybridize, even if cross-pollination was possible.

I hope that my assessment of some of the risks commonly associated with the development of herbicide-resistant crops has been helpful. Please contact me if you have any questions.

Sincerely,

Michael D. K. Owen
Professor and
Weed Science Extension

MDKO:[illegible]

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